December 2014

AEROSPACE AMERICA

2014 IN REVIEW

TWO BAD DAYS

Questioning conventional wisdom after Antares, Virgin Galactic/Page 4

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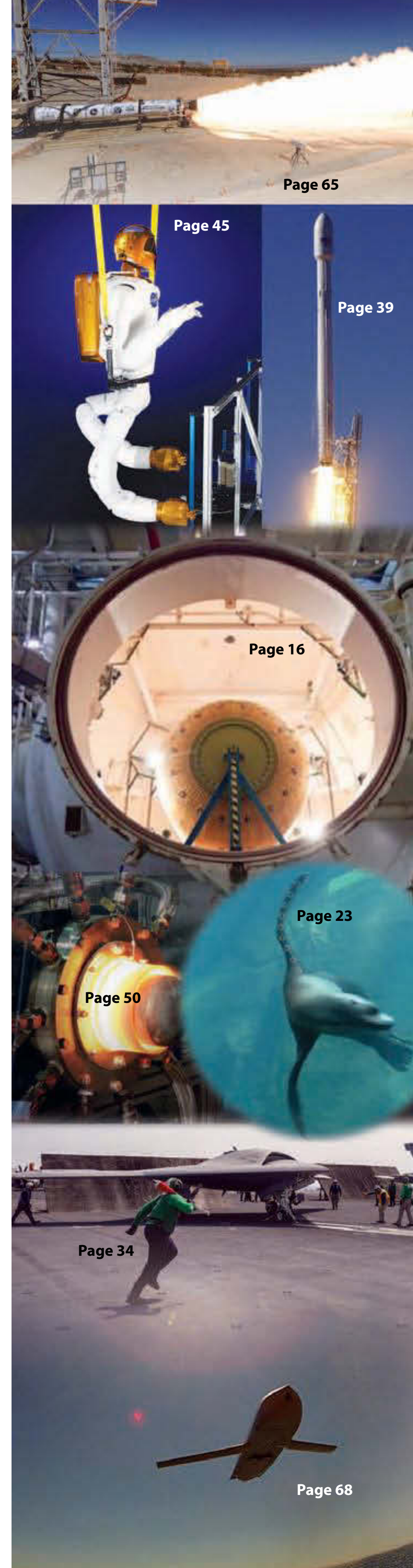
AEROSPACE AMERICA

December 2014

THE YEAR IN REVIEW

The most important developments as described by AIAA's Technical and Program Committees

BULLETIN



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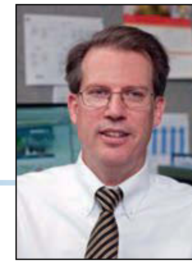
Shaping the Future of Aerospace

Editor's Notebook



Finishing strong in 2014

I've never seen a period richer with emotions for space exploration and adventure enthusiasts than the closing weeks of 2014. There were the cries of awe and fright from onlookers when an unmanned Antares rocket exploded. Then came the soul-rattling loss of SpaceShipTwo, followed by the hugs of joy in a European Space Agency control room with confirmation that the Philae spacecraft had touched down on Comet 67P/Churyumov-Gerasimenko.

These events are good reminders that when we go to space, we learn things about ourselves and our societies. Whether there are people aboard or robots with cameras, space missions are always human endeavors. Each success or loss changes us and hopefully strengthens us.

Richard Branson sounded visibly shaken when he appeared at a televised press briefing at Mojave, California, after the death of SpaceShipTwo co-pilot Michael Alsbury. "We would love to finish what we started some years ago," Branson said in a subdued voice. There was a tone of doubt about the future, but it was short-lived. A week later, Virgin Galactic posted a statement saying that among the condolences pouring in were requests to "take courage" from the accident. The company said it would do so by continuing work on the second SpaceShipTwo with "heightened resolve."

For sure, Branson and Virgin Galactic's prospective customers will never look at their endeavor the same way. They will have a heightened sense of the human risks that might always be inherent in riding a rocket to the fringes of space and back.

In the case of the comet landing, the images of the descent taken from the Rosetta spacecraft and those taken by the Philae lander were astounding. The scale of the media coverage should answer the questions about whether humanity can get excited about robotic missions. The answer is a resounding yes. Studying a comet in situ, even if only for a short while, is an amazing achievement. Europe can now assess the landing technologies and possibly improve them. Those planning similarly bold missions can make their cases with greater confidence.

Not all the lessons from the Philae mission were quite so cosmic. Project scientist Matt Taylor publicly apologized for wearing a shirt covered with drawings of scantily clad women. The shirt was, as Taylor put it, a "big mistake." It offended women and should offend men who see the value in a fully respectful workplace. Taylor seemed genuinely contrite about this teachable moment in what remains an impressive triumph for the European Space Agency and its partners.

Onward and upward.

Ben Iannotta
Editor-in-Chief

More to say about biofuels

It is indeed heartening that new synthetic paths to precursors for biofuels are being developed [*"Biofuels now," October, page 30*].

Unfortunately, these articles never delve into the question of how much net energy is being produced from biomass. Beyond the costly growing and harvesting of plant material, each process has to dehydrate or separate from the fermentation broth the alcohols from the rector slurry. Getting the alcohol (particularly ethanol) from water is an energy-intensive step. Ethanol in the U.S. is the most heavily subsidized fuel and would not stand by itself if it were not supported by tax credits. The moral question of using an edible plant material or waste to produce jet or car fuels when people in the world are starving is something that doesn't appear to be addressed either.

When we can use the bagasse or inedible grasses as feedstock, then I will get excited. Until then, using coal as the feedstock is the most tried-and-true method we have, including processes for CO2 capture during the generation of clean liquid fuels. That research was done in the '70s (Project Independence) and tested with Air Force aircraft.

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All letters addressed to the editor are considered to be submitted for possible publication, unless it is expressly stated otherwise. All letters are subject to editing for length and to author response. Letters should be sent to: Correspondence, Aerospace America, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, or by email to: beni@aiaa.org.

Correction

The graphic accompanying the article "*Biofuels now*" [*October, page 33*] contained an inaccurate rendering of a farnesene molecule. We've updated the online edition of the magazine with the correct molecule.

✈✈✈

An illustration accompanying the Analysis article "*Commercial Crew Insights*" [*November, page 19*] incorrectly highlighted one of the proposed vehicles as a winner in NASA's Commercial Crew program. The winning vehicles were Boeing's CST-100 and SpaceX's Dragon v2. The error has been corrected in the digital edition.

With the industry eager to understand and move beyond two launch failures in a matter of days, Teal Group analyst **Marco Cáceres** examines the strategies that brought the industry to this point.

TWO BAD DAYS

The risks of minimalist flight testing

The deadly SpaceShipTwo crash raises fresh questions over how much testing is enough before sending people up.

The failed flight of Virgin Galactic's SpaceShipTwo Enterprise was the 54th test flight of the suborbital space plane, although only four of these were rocket powered. The flights began in 2010 and had been scheduled to continue into next year. A total of 140 test flights were planned before commencing commercial operations, which means that had Enterprise not failed, it would have flown another 86 times before being qualified to begin carrying paying passengers. As Virgin Galactic founder Richard Branson told talk show host David Letterman a few weeks before the accident, "From now until March [2015] there will be many test flights. There will be many test flights actually into space." The indication was that there would be an intense period of test flights over the next seven months.

National Transportation Safety Board

What is sometimes compromised whenever one accelerates the development of rockets is flight testing. It is possible to field safe and dependable vehicles with a minimal number of test flights, but now, with the advent of the commercial space tourism industry, the risks of this minimalist flight testing culture are much greater because human lives are at stake. If an Antares rocket blows up, you lose the rocket, the satellite payload and the space station cargo. If a Virgin Galactic space plane goes down, it's an entirely different level of loss.

At first glance, the plan for 140 flights seemed adequate. It showed seriousness on the part of Branson and his company, and was reminiscent of 1959-1968 when NASA conducted 199 test flights of its X-15 rocket-powered aircraft. Like the Enterprise, the X-15 was also piloted and air-launched. Unlike the Enterprise, though, nearly all of the X-15 test flights were powered, meaning the rocket engine was turned on and the vehicle flew of its own

(Continued on page 6)

ANALYSIS
BY MARCO CÁCERES

The SpaceX effect

In the the wake of the Antares failure, SpaceX's approach of developing all-new engines contrasts sharply with the strategy of using old Russian engines.

The failed launch of Orbital Sciences Antares 130 rocket in late October has again raised concerns about the use of Russian-made engines by U.S. launch companies.

Although we don't yet know what went wrong, we know that the first stage of an Antares is powered by two engines built by the Kuznetsov Design Bureau in the 1960s. The engines, designated NK-33, were purchased by Aerojet during the 1990s, refurbished, and sold to Orbital Sciences as the AJ26 in 2010 for use on Antares. Another U.S. company, United Launch Alliance, uses the Russian Energomash RD-180 engine on the first stage of the Atlas 5 rocket.

The reliance on Russian engines has raised concerns about their continued availability. After the U.S. and Europe imposed sanctions against Russia over the conflict in Ukraine, Russian Deputy Prime Minister Dmitryi Rogozin threatened to ban exports of the RD-180 to RD AMROSS, the Florida-based company that sells the engines to ULA, which launches many U.S. government military and scientific payloads. That has fueled a push in Congress for a U.S.-made alternative to the RD-180.

But the more fundamental question that keeps popping up is, "Why are we even buying Russian engines to begin with?" The answer is simple: The engines are among the most powerful in the world, and they're much less expensive than anything available in the U.S. The NK-33 and RD-180 have exceedingly high thrust-to-weight ratios and they can be bought at bargain prices. Aerojet Rocketdyne reportedly paid $1 million for each NK-33, while the RD-180s have been sold by Energomash to the U.S. for $6 million. The underlying assumption in the Atlas 5 and Antares programs was that the fastest and most cost-effective way to develop rockets with the lift capacities required by the U.S. Air Force and NASA was to go with readily available Russian liquid-fuel engines for the first stage. The established U.S. launch companies saw little reason to consider using homegrown engines.

NASA

The second-guessing of this strategy has been intensified by the emergence of SpaceX as a major provider of launch services. SpaceX has managed to break into a market that is technologically and financially demanding and extremely competitive. Yet it has done so relatively quickly with reliable rockets that it produces entirely at its facilities in California. SpaceX has demonstrated that it is possible for a vertically integrated company to be a

(Continued on page 7)

The risks of minimalist flight testing

(Continued from page 4)

accord. For Enterprise, 50 of the 54 tests involved takeoffs of the WhiteKnightTwo carrier aircraft with the Enterprise attached to it. WhiteKnightTwo would fly to an altitude of about 50,000 feet and then release Enterprise, after which the space plane would glide down and land on a runway.

This raises the issue of how many of the remaining 86 flights of the Enterprise were planned to be powered, particularly in light of preliminary findings by the National Transportation Safety Board that a pilot's actions may have contributed to the early deployment of the space plane's "feathering" descent system — a mechanism that rotates the aircraft's tail booms upward — which could have caused the crash of the vehicle.

The Enterprise made its first powered test flight on April 29, 2013; its second on Sept. 13, 2013; its third on Jan. 10, 2014; and its fourth on Oct. 31. Realistically, you have to wonder how many powered flights Virgin Galactic could have conducted through March 2015 before it would have felt compelled to announce that start of commercial operations. The Virgin Galactic plan seemed more than reasonable to establish the reliability and safety of a rocket vehicle, especially given the current tendency by space launch companies to test fly their new rockets once or twice before declaring them ready for operations. An example of this is Orbital Sciences and its Antares, which was first test flown carrying a dummy payload on April 21, 2013. That was followed by a demonstration flight carrying the Cygnus capsule on Sept. 18, 2013, to show that the capsule could dock with the International Space Station, and its first operational flight on Jan. 9, 2014, with Cygnus delivering cargo to the ISS. The rocket flew a second Cygnus resupply mission to the ISS on July 13, 2014, before the failed launch on Oct. 28. So, there was one test flight before Antares was considered fit for active service.

In the 1990s, Arianespace conducted three test flights of its new Ariane 5 rocket, but even those missions were really more operational flights, because they carried actual satellites, not dummy payloads. However, at least those satellites were relatively small and inexpensive ones for the European Space Agency, which had a vested financial interest in the development of the Ariane 5. In the case of the doomed Delta 3, Boeing didn't even bother with test flights.

The Delta 3's inaugural mission on August 26, 1998, carried the Galaxy 10 spacecraft — a $225 million, 8,543-pound commercial TV broadcasting satellite for PanAmSat. The launch failed, but Boeing wasn't deterred. Instead of pausing and trying a couple of test flights, the company attempted a second Delta 3 commercial launch on May 4, 1999, and again failed. That time it involved a $145 million, 9,400-pound telecommunications satellite for Orion Network Systems.

Ultimately, Boeing did opt for a test flight. On Aug. 23, 2000, a Delta 3 launched a dummy payload designated the DM-F3, designed to simulate the Hughes Space and Communications HS-601 satellite. By then, it was too late. The Delta 3 had lost the market's confidence, and Boeing terminated the program.

The obvious question is: Why was Boeing in such a hurry? Answer: The commercial satellite market was perceived as being at the cusp of a boom period. The demand for commercial launch services was growing, and Boeing wanted to be a major player with its Delta 3. The company was under pressure to introduce the vehicle and commence operations as quickly as possible. It was working under a $1.5 billion contract from Hughes to provide 10 firm Delta 3 launches, plus options for 10 or more launches. By 1996, the Delta 3 program already had an order backlog of 20 launches through 2002. Arianespace was also facing pressure to introduce its Ariane 5 to take advantage of the coming boom in satellite launch orders.

As to Orbital Sciences, it may have felt the need to speed up development of its Antares to take advantage of an opportunity that presented itself on Oct. 18, 2007, when NASA canceled its Commercial Orbital Transportation Services contract with Rocketplane Kistler. The contract was recompeted under the Commercial Resupply Services program, and Orbital won a $1.9 billion contract on Dec. 23, 2008, to provide eight cargo supply flights to the International Space Station using its Taurus 2 (subsequently renamed Antares) and Cygnus capsule combo.

The SpaceX effect
(Continued from page 5)

launch industry leader. That is starting to unnerve large launch companies that have seldom felt threatened by newcomers.

Other private companies have tried — and failed — to introduce new launch vehicles. That's why when SpaceX was founded in 2002, it wasn't taken seriously by the industry.

SpaceX initially offered a small-lift rocket called the Falcon 1, priced at $5.9 million per launch, less than half the going rate for other small U.S. launch vehicles at the time. The industry viewed the price as a marketing gimmick. The first three Falcon 1 launch attempts — in 2006, 2007 and 2008 — failed and SpaceX raised its launch price by 30 percent. Three consecutive failures should have meant the end of a new launch company, but SpaceX kept at it. Less than two months after Falcon 1's third failure, SpaceX tried again and succeeded. The company conducted another good launch before deciding to retire the Falcon 1 and move on to its heavy-lift Falcon 9, which began launching in 2010. Through the end of October 2014, the Falcon 9 has launched 13 missions.

SpaceX is currently working under a $1.6 billion contract to provide cargo resupply services to the International Space Station using its newer, larger Falcon 9 v1.1 and Dragon cargo capsule. In September, NASA awarded a $2.6 billion contract to SpaceX to develop a system, using the Falcon 9 and a manned version of Dragon, for transporting crews to and from ISS. The company is also on the verge of having the Falcon 9 certified by the Air Force as a potential launch provider for Evolved Expendable Launch Vehicle payloads.

Additionally, SpaceX has been competing successfully in the commercial launch market. Over the past year, the company has launched four commercial communications satellites destined for geostationary orbits, plus a batch of Orbcomm mobile comsats to low-Earth orbit. It has won contracts to launch more than two dozen commercial satellites for companies around the world, as well as contracts to launch satellites for the Air Force, NASA, the German armed forces, and the space agencies of Argentina, Canada, Taiwan and Turkmenistan.

SpaceX has been winning contracts in every segment of the launch market. The company has a reliable rocket priced at half, or less, the prevailing prices of comparable vehicles, and it has been around long enough that it is now viewed as part of the mainstream of the industry, giving it the credibility that it may have lacked just a few years ago. This presents a potential nightmare for traditional players in the launch market.

There is increased pressure on companies like ULA and Orbital Sciences to reduce the cost of their rocket programs so that they can be competitive with SpaceX. One way to do this is to increase launch volume by more aggressively marketing the vehicles commercially. Lockheed Martin has moved in this direction with its Atlas 5 during the past year. Another way is to shake up corporate leadership to come up with new ideas. That would explain ULA's move in August to replace CEO Michael Gass with Tory Bruno, former president of Lockheed Martin Strategic and Missile Defense Systems. ULA is a joint venture of Lockheed and Boeing.

Europe's Arianespace is also starting to feel pressure to reduce its costs. The consortium is struggling to decide how to proceed with development of the Ariane 6 rocket. One of the drivers of the debate is the question of how to dramatically reduce launch costs compared with its Ariane 5 ECA. The Europeans are even considering a fundamental industrial restructuring of Arianespace to make it more competitive.

It's almost impossible to get anyone within the European space industry to admit that they underestimated SpaceX and its impact on the market. But the Europeans are clearly concerned. France's space minister, Geneviève Fioraso, has criticized SpaceX for "dumping" its rockets on the commercial market. She and others in Europe also believe SpaceX has been unfairly bolstered by U.S. government contracts. The fact remains: The Europeans are reacting to SpaceX.

Perhaps the best indicator of the "SpaceX effect" can be found in comments made shortly after the Antares failure by Chris Chadwick, the president and CEO of Boeing Defense, Space & Security. In a Bloomberg News article, Chadwick was quoted as saying that SpaceX founder and president Elon Musk and others are bringing "disruptive ideas" to the space industry. "It ensures that we stay on our toes," Chadwick said.

Marco Cáceres is the senior space analyst at Teal Group in Fairfax, Virginia.

Research in adaptability

by Louis Centolanza

*The **Adaptive Structures Technical Committee** supports work to enable aircraft to adapt to changing environmental conditions during flight.*

Structurally efficient wings and quiet, low-speed performance for next-generation aircraft require a change in control paradigms to address the range of maneuver and nominal/off-nominal flight conditions. Challenges to implementing control technologies such as gust load alleviation, circulation control and flutter suppression include interactions of the aerodynamic nonlinearities, low-weight/flexible structures and control. NASA's Armstrong Flight Research Center and Tao Systems are developing a **localized sensing methodology** that separates aerodynamic forces and movements into circulatory and non-circulatory components to construct physics-based unsteady aerodynamic models and control each span station component independently.

NASA also partnered with the Air Force Research Laboratory for the Environmentally Responsible Aviation project, a series of flight tests to demonstrate the viability of full-scale **Adaptive Compliant Trailing Edge** flaps. A compliant flap is being designed and fabricated by FlexSys for integration and flight research on the NASA Gulfstream 3 Subsonic Research Aircraft Testbed. In-flight structural and aerodynamic data will verify analysis and design techniques for adaptive structures.


NASA

A modified Gulfstream 3 is NASA's testbed for flexible-wing-flap research.

In other research, AFRL fabricated and tested a 6-foot-span **variable camber compliant wing**. A non-stretchable, single-piece carbon fiber composite skin enables active camber change between the NACA 2410 and NACA 8410 airfoils without discrete control surfaces. Vertical wind tunnel testing included flow and structural response measurements as well as flow visualization and digital image correlation. AFRL is also collaborating with Metis Design to integrate structural health monitoring hardware onto the Space Test Program-H5 payload. Flight hardware includes distributed SHM nodes coupled with piezoelectric beamforming elements and precision triaxial accelerometers for pallet structural assessment from assembly through integration and year-long testing on the International Space Station.

A project under the Consortium for Research and Innovation in Aerospace in Quebec is designing and manufacturing a **morphing** Bombardier-type aircraft wing tip controlled using electric actuators and pressure sensors. Canadian and Italian partners are Bombardier Aerospace, Thales Canada, Institute for Aerospace Research-National Research Council, École de technologie supérieure, École Polytechnique, Alenia, Centro Italiano Ricerche Aerospaziali and the University of Naples. The aim of morphing is the delay of wing flow transition and improvement of aileron aerodynamic performance. The aerodynamic analysis will be validated with subsonic wind tunnel testing by the Canadian National Research Council's National Institute for Aerospace Research.

Adaptive structures research continues at several universities. Arizona State University is developing hybrid and multifunctional **smart particles** that can be embedded in polymer matrix composites, exhibiting stress-sensitive properties such as changes in color and conductivity under loading. The smart material comprises tris-(cinnamoyloxymethyl)-ethane monomer, which further converts to cyclobutane, a mechanophore formed by exposing TCE to ultraviolet light. The cyclobutane rings cleave under post-yield loading and efficiently generate fluorescence emission.

Morphing skins developed at the Harbin Institute of Technology in China include elastic fiber enhanced styrene-based shape memory polymer skins for variable camber micro air vehicle wings. A second morphing skin based on carbon fiber reinforced plastic rods and Kevlar-reinforced rubber composite can be used on sweeping wings.

The University of Maryland is investigating improved autonomy for small unmanned autonomous vehicles using **bioinspired control** based on the human-animal metaphor of interaction between service canines and human handlers. The vehicle, Aerial K9, will result in a reduction of human operator workload. Control commands issued by the first responder are canine cues or gestures such as heel, come, stay or search.

Mississippi State University, in association with the Indian Institute of Science, developed the wavelet-based spectral finite element, or **WSFE**, method for wave propagation in thin to moderately thick anisotropic composite laminates. WSFE yields accurate results with high computational efficiency for wave motion at high frequencies and is suitable for solving the inverse problem of structural health monitoring. The method was extended to model and perform SHM for built-up structures and adhesively bonded joints.

Artist's concept of the V-280 Valor tiltrotor.

Bell Helicopter

Rotorcraft, reusability mark year in design

by Sidney Rowe

*The **Design Engineering Technical Committee** promotes the development and dissemination of technologies that assist design engineers in defining practical aerospace products.*

A team headed by Bell Helicopter and Lockheed and another by Sikorsky and Boeing have been selected to produce and fly rotorcraft in 2017 for the U.S. Army-administered Joint Multi-Role Technology Demonstrator program. JMR will be the technology development phase of the **Future Vertical Lift** program, which aims to field faster, long-range successors to approximately 4,000 medium-sized helicopters flown by the military today, including Army Apaches and Black Hawks and aircraft flown by the Navy and Marines. Bell, with Lockheed providing electronics, is developing the V-280 Valor tiltrotor, which is intended to fly at top speed of 280 knots, can fly at double the speed and has twice the range of any of the Army's current helicopters. The rotors can move from their conventional position for takeoff and landing to act as propellers for forward flight. Sikorsky-Boeing's SB-1 Defiant helicopter has coaxial, counter-rotating rigid main rotor blades, and a pusher propeller in the rear that can accelerate and decelerate the aircraft.

In the **space launch** domain, SpaceX, one of NASA's Commercial Orbital Transportation Services partners, said it has demonstrated reusability of the Falcon 9. Following the July launch of six Orbcomm communciations satellites, the Falcon 9 launcher's first stage re-entered the atmosphere and soft landed in the Atlantic Ocean, the company announced on its website. "This test confirms that the Falcon 9 booster is able consistently to reenter from space at hypersonic velocity, restart main engines twice, deploy landing legs and touch down at near zero velocity," the company said. The ultimate goal is to soft land back at Cape Canaveral, which would enable refurbishment and reflight within a year.

In September, NASA announced its selection of SpaceX with its Dragon capsules and Boeing with its CST-100 to begin transporting astronauts to and from the International Space Station by the end of 2017.

For aircraft **sonic boom control**, researchers have been using cutting-edge testing to explore designs that show promise for reducing sonic boom levels. Studies have determined that several factors, including shaping and positioning components, create the makeup of a sonic boom. These factors allow engineers to tailor a boom signature through design to minimize the loudness of the boom it produces in flight. New concepts retain characteristics of a needle nose, a sleek fuselage and swept wings from heritage aircraft. Lockheed Martin proposed a design that mounts two engines under the wing in a traditional configuration with an additional centerline engine above the wing. Boeing proposed two top-mounted engines in a departure from historical aircraft design. With conventional mounting, the shape of the wing must be tailored to diffuse the shock waves. If the engines are above the wing, the shock wave can be directed upward and not affect the ground signature.

SpaceX

The first stage of a SpaceX Falcon 9 launcher made a soft landing in the Atlantic Ocean after a satellite-deployment mission in July.

The widening impact of multidisciplinary design

by Karen Willcox

*The **Multidisciplinary Design Optimization Technical Committee** provides a forum for those active in development, application and teaching of a formal design methodology based on the integration of disciplinary analyses and sensitivity analyses, optimization and artificial intelligence.*

The sophistication of multidisciplinary design optimization methods and tools continues to grow, as does MDO's impact throughout the design of aerospace systems. This year has seen notable developments across design applications that include aircraft, space systems, turbomachinery, unmanned vehicles, robotic systems and air transportation networks.

NASA's Multidisciplinary Design Analysis and Optimization Branch continued development of the **OpenMDAO** framework, focusing on computing multidisciplinary derivatives (design sensitivities) via the coupled-adjoint method. This was done in collaboration with the University of Michigan MDOlab, demonstrating the numerical methods in a new open-source benchmark problem that optimizes the design and operation of a satellite.

Iowa State and Penn State joined forces to investigate the use of trade-space exploration and visualization tools to support **value-driven design** of complex engineered systems. The Virtual Reality Applications Center at Iowa State developed a method to visualize **n-dimensional optimization** problems using graphics-processing-unit, or GPU, parallelized self-organizing maps. The method allows visualizations of datasets for millions of points to be created in minutes for use in design trade-off decisions.

MDO methods are being scaled to handle systems of increasing complexity through **surrogate** and **multifidelity** methods — methods that employ principled approximations to accelerate computations and that combine different tools across a range of simulation fidelities. Many of these developments exploit a growing connection with machine learning methods. The McGill University Systems Optimization Lab developed an adaptive surrogate optimization framework for direct search algorithms using dynamic tree regression models (with École Polytechnique de Montreal), and extended a system-of-systems methodology for air transportation design to include route network configuration and aircraft design variables. The University of Arizona Computational Optimal Design of Engineering Systems, or CODES, laboratory developed a classification-based approach for model updating. This **"fidelity maps" approach** can tackle a large number of responses without assumptions on their correlation structure and is particularly suited for vibration problems. The Massachusetts Institute of Technology developed a multifidelity formulation for incorporating information from multiple information sources, including surrogate models and previously evaluated designs, and demonstrated it for aircraft conceptual design. The University of Cambridge deployed its multifidelity optimization approach on the combined aerodynamic configuration selection and refinement of a complete turbofan core engine compression system. The University of Southampton developed large-scale and multifidelity optimization algorithms.

Iowa State University

The Virtual Reality Applications Center at Iowa State.

Increased complexity is also achieved by exploiting synergies between algorithms and computer hardware. Iowa State used GPUs for improving the efficiency of **particle swarm optimization**, resulting in solution improvement time by as much as five times when solving complex multimodal unconstrained optimization problems, with no noticeable decrease in solution quality or reliability.

The Air Force Research Laboratory's Multidisciplinary Science and Technology Center focused on incorporating installed propulsion (inlet, engine and nozzle) effects into system-level MDO along with power and thermal management models to enable a thermal balance of the vehicle during conceptual design.

The University of Illinois, in collaboration with the Jet Propulsion Laboratory, investigated new MDO strategies for space observatory **orientation and jitter reduction**. Illinois developed new co-design methodologies that balance physical and control system design optimization to study design principles for active and autonomous engineering systems. Two reconfigurable delta robot and vibration isolation system testbeds support exploration of physical and control system changes, enabling co-design method validation.

The University of Southhampton continues to investigate techniques for controlling the balance of flexibility, conciseness and robustness in parametric geometry models while embedding intelligence, designer knowledge and best practices within computer-aided design systems and MDO frameworks.

The AIAA Aerodynamic Design Optimization Discussion Group released a series of benchmarks for testing and comparing strategies for aerodynamic shape optimization (www.aiaa.org). The first papers that tackled these problems were presented at a special session at SciTech 2014. These efforts are paving the way toward a high-fidelity MDO benchmark problem.

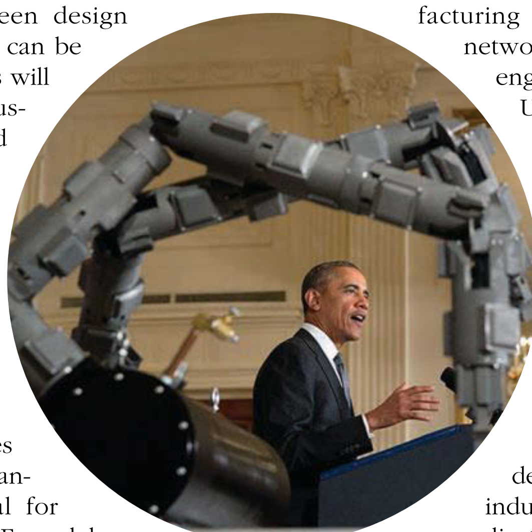
Making the most of uncertainty

by Barron Bichon, Girish Modgil, Harry Hilton and Shyama Kumari

The ***Non-Deterministic Approaches Technical Committee*** *advances the art, science and cross-cutting technologies required for applying non-deterministic modeling and analysis to aerospace systems.*

Non-deterministic methodologies and implementation strategies enable numerical simulation subject to uncertain inputs, variable processes and model-form uncertainties, which provide information on ranges of possible component and system behavior rather than unique, deterministic predictions. Analysis and life assessment of a component using non-deterministic approaches increases the trustworthiness of the analysis, and proves to be of great value in the virtual prototyping process that is becoming a standard in current design engineering practice. As non-deterministic computational models are relied upon more and more for decision-making, it has become increasingly important to quantify the uncertainties within these models and the impact they have on the accuracy of the models' predictions.

Integrated computational materials engineering is playing an increasingly large role in the design and certification of manufactured components and systems. ICME models can have a large impact in manufacturing where tradeoffs between design and material properties can be explored. These models will be integral in the industry-government-funded **American Lightweight Materials Manufacturing Innovation Institute**, founded this year as a hub on the new National Network for Manufacturing Innovation, which is focused on re-establishing the United States as a global leader in manufacturing. A key goal for ALMMII is that all ICME model development activities include plans for verification, validation and uncertainty quantification, or V&V-UQ.



White House

President Barack Obama announces the creation of the American Lightweight Materials Manufacturing Innovation Institute and the Digital Manufacturing and Design Innovation Institute.

In a similar vein, DARPA is entering the second phase of its **Open Manufacturing** program "to lower the cost and speed the delivery of high-quality manufactured goods with predictable performance by creating a manufacturing framework that captures factory-floor and materials processing variability and integrates probabilistic computational tools, informatics systems, and rapid qualification approaches." DARPA also announced the new Materials Development for Platforms program, which aims to leverage ICME models, manufacturing process control, and V&V-UQ concepts to accelerate the development and deployment of new materials on defense platforms.

The Materials Engineering Department at Southwest Research Institute has been heavily involved in these efforts and, jointly with staff from the Air Force Research Laboratory, conducted a tutorial titled "Verification and Validation Best Practices for ICME" at AIAA's SciTech 2014 Forum. This tutorial will be conducted again at SciTech 2015, along with a series of special sessions on ICME organized by the Materials; Structures; Multidisciplinary Design Optimization; and Non-Deterministic Approaches Technical Committees.

The **Digital Manufacturing and Design Innovation Institute** was also announced in February, as part of the Obama administration's National Network for Manufacturing Innovation initiative. The DMDII team is led by UI Labs, a Chicago-based nonprofit. DMDII is backed by more than 500 companies and over 315 local, regional and national organizations, community colleges and Manufacturing Extension Partnership networks. Six of the top 20 engineering schools in the U.S. are also members.

The mission of DMDII is to establish a state-of-the-art proving ground for digital manufacturing and design that links IT tools, standards, models, sensors, controls, practices and skills, and transition these tools to the U.S. design and manufacturing industrial base for full-scale application.

In addition, industry-academia cooperative research programs by personnel from IMI, Technion, Mississippi State University and the University of Illinois at Urbana-Champaign have been operating for a number of years. The purpose of these collaborations is to conduct experimental and analytical investigations into the stochastic viscoelastic characterizations of polymers. These investigations include creep, relaxation and wave propagation phenomena. Results show overwhelmingly that relaxation moduli and creep compliances not only behave non-deterministically, but that their probability density functions, means and variances change dramatically with time.

Space structures for communication, exploration

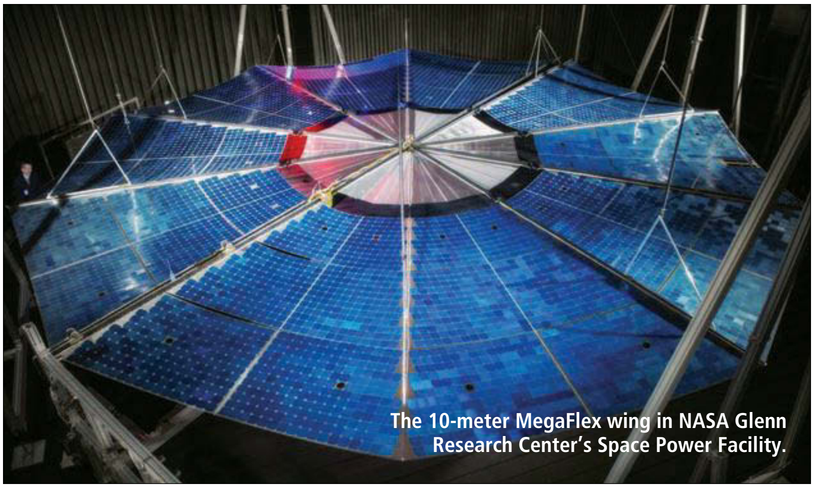
by Gregory L. Davis, William Tandy, Thomas Campbell, Dave Murphy, Brian Spence, Les Johnson and Timothy Collins

The ***Spacecraft Structures Technical Committee,*** *formerly the Gossamer Spacecraft Program Committee, focuses on the unique challenges associated with the design, analysis, fabrication, and testing of spacecraft structures.*

Ball Aerospace and Technologies recently completed testing in Boulder, Colo., of a foldable, membrane-based telescope called **MOIRE**, for the Membrane Optical Imager for Real-Time Exploitation platform. An orbital version would consist of a 20-meter-diameter optic to provide real-time video capabilities from geosynchronous orbit. The current development phase tested a complete optic system with a 5-meter-diameter membrane optic. Three MOIRE-related papers were presented at AIAA's SciTech 2014 conference, covering material and structural analyses, as well as preliminary results.

In the radio frequency domain, Harris Corp. has developed, built and tested **unfurlable** and **fixed-mesh reflector** designs with demonstrated performance up to Ka-band and higher frequencies. Enabling this FMR development is a new, high-density, gold-plated mesh reflector. The lightweight FMR structure leverages a flight proven, lightweight advanced composite sandwich panel egg-crate construction to support the mesh. For large sizes of approximately 3.5 meters, total reflector mass savings approaching 50 percent of a similar solid graphite reflector can be achieved. Spacecraft mass savings can also be realized from this design due to its unique characteristic that virtually no acoustic loading is generated from the reflector surface. Concurrent with the ongoing FMR qualification program, flight article production is underway on the world's first Ka-band unfurlable mesh reflectors and system level testing was expected to begin in Melbourne, Florida, in September.

NASA



The 10-meter MegaFlex wing in NASA Glenn Research Center's Space Power Facility.

The Membrane Optical Imager for Real-Time Exploitation telescope undergoes ground testing at Ball Aerospace.

DARPA

This year has also seen continuing progress in lightweight **space power deployables**. Under a NASA technology development contract, ATK Space Systems has advanced the flight-readiness of its **MegaFlex** array system to Technical Readiness Level 6, an activity supported by component testing in unique environments, including high-density plasma. Testing was completed on a 10-meter flight-like wing at NASA Glenn Research Center's Space Power Facility outside of Cleveland. Under that same program, Deployable Space Systems Inc., with the support of NASA Glenn, Langley Research Center in Virginia and the Jet Propulsion Laboratory in Pasadena, has significantly matured its **Roll-Out Solar Array** — ROSA — and derived Mega-ROSA solar array system technology to TRL 6. The array underwent detailed design, analysis, build and full spectrum validation testing at Boeing's test facility in El Segundo, California, and has resulted in a high TRL that will facilitate near-term, high-power, high-voltage missions requiring 50 kilowatts to 1 megawatt of power.

Complementary to its work on the Sunjammer solar sail mission, NASA also began development work this year on two CubeSat-class deep space solar sail missions, each using a solar sail measuring approximately 85 square meters. One of these missions, the **Near Earth Asteroid Scout**, will carry an imager to provide initial reconnaissance of an asteroid for possible future human exploration. Another mission, the **Lunar Flashlight**, will study the significant ice deposits in the Moon's permanently shadowed craters. Its solar sail will be used as a mirror to steer sunlight into the craters while a spectrometer analyzes the reflected light to determine the composition of what is being illuminated. Both of these missions are planned as secondary payloads on the Space Launch System Exploration Mission 1, which will be the first flight of the SLS rocket.

Dynamics research focuses on rotorcraft

by Daniel Griffith and the Structural Dynamics Technical Committee

The ***Structural Dynamics Technical Committee*** *focuses on the interactions among a host of forces on aircraft, rocket and spacecraft structures.*

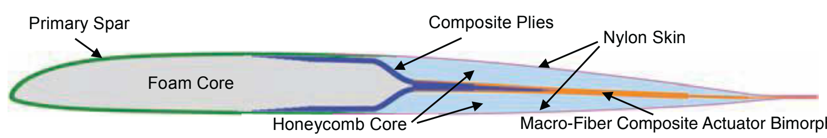
The U.S. Army Research Laboratory Vehicle Technology Directorate is researching passive and adaptive technologies for rotorcraft aeroelastic/aeromechanical stability augmentation. Researchers at Aberdeen Proving Ground in Maryland have conducted an exploratory micromechanics modeling effort to demonstrate that **nanocomposites** — carbon nanotube matrix inclusions — may provide sufficient structural damping augmentation to enable aeroelastically/aeromechanically stable rotor blades without the need for auxiliary dampers. Potential benefits include lower maintenance burdens for future Army rotorcraft as well as enabling advanced design concepts. Follow-on experimental nanocomposite characterizations are underway in collaboration with the University of Florida and Texas A&M University.

In addition, ARL/VTD researchers at NASA's Langley Research Center are developing an advanced active-flap design for helicopter rotor blades. The **Continuous Trailing-Edge Flap** uses a piezoelectric bimorph to change blade camber during flight, which may provide sufficient authority for primary flight control. Its monolithic construction eliminates mechanical hinges in order to improve system reliability, a weakness of current active-flap technologies. Prototypes are being constructed for wind-tunnel testing and validation of the concept.

A unique flight test was conducted at the National Research Council of Canada using its Bell 412 helicopter to investigate the biomedical effects of aircrew exposure to **whole-body vibration**, or WBV. This flight trial was conducted under the auspices of the NRC's recently launched Working and Travelling on Aircraft initiative, which spearheads research in the aircraft cabin and cockpit human-factors domain to enhance the situational awareness, safety and comfort of aircrew and passengers. Increasingly, the potential causative role of WBV and associated factors such as aircrew postures, aircraft maneuvers and the increase in head-mounted mass due to the use of night-vision devices and head-up displays, are being recognized in relation to occupational injuries such as neck strain and back pain, which are prevalent among helicopter aircrews.

The NRC helicopter was instrumented to synchronously acquire mechanical and physiological data using a variety of sensors. Test instrumentation included accelerometers to measure aircrew vibration, heart rate and respiration monitors, electromyography and electrooculography electrodes to measure neck muscle activity and eye movement, galvanic skin response sensors to evaluate stress, goniometers to measure neck angles, motion trackers to record head movement, and video cameras to capture multiple views. This flight trial yielded a comprehensive set of data allowing researchers to quantify the physiological responses of helicopter occupants to their operating environment under representative flight conditions.

The Air Force Institute of Technology has been carrying out research in the area of **mistuning** within a turbine rotor due to geometric imperfections. This mistuning is established by evaluating the variation of each blade's effect on the rotor's frequency response function. The individual rotor is subjected to a software program associated with the aerodynamics creating movement in that rotor as it undergoes its design rotation, and thus its important frequency response. An experiment is employed to ascertain the forced response and mistuning patterns for the rotor. Several items attributed to existing experimental inconsistencies were identified and their effects were realized during this research. These experimental items were signal input locations, response measurement locations and rotor alignment position. Accounting for these experimental variables, this research develops a process that enables consistent rotor forced response results, independent of its orientation on the test stand. The result is a specification that will allow experimentation to determine the extent of rotor mistuning, which can lead to high-cycle fatigue. ⩓



An advanced active-flap design for helicopter rotor blades is being developed by the U.S. Army Research Laboratory Vehicle Technology Directorate.

U.S. Army Research Laboratory

National Research Council of Canada

An instrumented Bell 412 helicopter provided insights into the effects of whole-body vibration on aircrews under research conducted by the National Research Council of Canada.

Research seeks lighter, more versatile structures

by Harry H. Hilton

*The **Structures Technical Committee** works on the development and application of theory, experiment, and operation in the design of aerospace structures.*

The **Air Force Institute of Technology** is working on a lighter-than-air vehicle and has considered structures such as a icosahedron and a celestial sphere. Findings are still being reviewed, but material properties and mistuned rotors are major issues. The study is developing advanced experimental and analytical approaches for the accurate assessment of turbine engine component life. Additional work will help quantify uncertainty propagation from the initial modeling and computational predictions to the experimental application and results.

NASA Langley Research Center is acquiring a state-of-the-art composites fabrication environment to support its research and technology development mission. This overall system is called **ISAAC**, for Integrated Structural Assembly of Advanced Composites. ISAAC's initial operational capability is a commercial robotic automated fiber placement system from Electroimpact Inc. with a multiple-degrees-of-freedom commercial robot platform, a tool changer mechanism and a specialized automated fiber placement end effector. Developments included advanced composite materials, structures, fabrication processes and technology.

An inflatable pressure vessel undergoes a creep burst test at NASA's Johnson Space Center to determine material properties, including failure pressures and creep times.

The University of Pisa's Civil and Industrial Engineering Department is conducting a research project, called IDINTOS, to design and manufacture an amphibious light aircraft with a PrandtlPlane box-wing configuration for small industries. Projects concluded with construction of a prototype with main and front retractable landing gears, tip wings of the **PrandtlPlane** configuration, fin and rudder, hull and two shrouded propellers.

NASA Johnson Space Center's **Inflatable Structures Team** performed an inflatable pressure vessel creep burst test. The 7.5-foot-diameter, 10-foot-long woven Vectran article was designed for 36 pounds per square inch gauge and tested to failure to help understand time-dependent, end-of-life properties. The structure was pressurized to an internal pressure of 145 psig (74 percent static burst pressure) until the structural restraint layer burst. In addition to creep performance, the results will be used to study the structure's loading and dynamic behavior.

Arizona State University's Adaptive Intelligent Materials & Systems Center and **Aerojet Rocketdyne** are developing stochastic multiphysics, multiscale modeling for improved analysis of carbon fiber reinforced ceramic matrix composites for advanced rocket propulsion applications. The effort focuses on accurate and efficient material characterization through serial sectioning and 3-D model reconstruction to study progressive damage models. Weave and tow architectures contain voids due to manufacturing, which are key model features.

The **Air Force Research Laboratory** and Lockheed Martin Aeronautics led efforts to benchmark composite progressive failure analysis tools for static loading conditions. AFRL's structures lab measured basic lamina properties of common graphite/epoxy and delivered them to 10 analysis teams for model calibration. After calibration, each team predicted stiffness, strength and damage characteristics of unnotched and open-hole tension and compression coupon tests of three different layups. The results varied with some predictions falling within 1 percent of the experimental mean while others were off by more than 25 percent.

An 18-foot-diameter tank built by Boeing was delivered to **NASA Marshall Space Flight Center**. The tank was then filled with liquid hydrogen at simulated launch condition pressures. This is the first time a tank of this size been proven to sustain the thermal environment of liquid hydrogen at these pressures. The design is more structurally efficient then its predecessors and represents significant technology achievements for NASA, Boeing and industry. The technology could prove beneficial to the U.S. launch industry and other industries that want to replace heavy metal components with lightweight composites.

SpaceX attached landing gear onto the Falcon 9 rocket that will launch the company's unmanned Dragon cargo capsule toward the International Space Station. This marks another step in SpaceX's quest to develop a fully reusable launch system. The launch vehicle will continue to make ocean landings and will not attempt a surface landing until precision control from hypersonic through subsonic regimes is achieved.

Purdue University is developing an accelerated certification process for aerospace composites in an effort to reduce costly physical testing requirements. The slightest design or material change increases costs and suppliers often publish material properties that become the basic information required to run virtual simulations, but this information is insufficient, requiring additional performance parameters.

Missile, fire threats investigated

by Ameer G. Mikhail, Gregory J. Czarnecki, Adam E. Goss, Alex G. Kurtz and John J. Murphy Jr.

*The **Survivability Technical Committee** promotes air and spacecraft survivability as a design discipline that includes such factors as crashworthiness and repairability.*

The shootdown of a Malaysia Airlines Boeing 777 at 33,000 feet over Ukraine highlights a new, high-altitude threat to commercial aircraft.

Laurent Errera

To better assess the survivability of an aircraft engine hit by an exploding warhead and fragments of a man-portable air defense system missile, or **MANPADS**, U.S. Air Force researchers performed static and precise dynamic missile tests resulting in three different blast pressure fields. The tests, conducted at Wright-Patterson Air Force Base, Ohio, included a missile case that contained residual rocket motor fuel. The results of the three pressure fields were collected, analyzed and used to improve the threat blast model fidelity for engine-damage simulation, which will be reflected in more accurate engine-damage predictions and assessments of aircraft vulnerability to MANPADS.

The ability of air crews to survive **onboard fires** was studied by a team of researchers from the Air Force, the Army Research Laboratory and Naval Air Systems Command. Investigators examined JP-8 fuel fires in a helicopter compartment test bed with different air ventilation conditions and rates. The first test series, at Wright-Patterson, was made with no air flow or ventilation, while the second, at Aberdeen Proving Ground, Maryland, included air flow and ventilation. Combustion product concentrations were measured and the effects of smoke and fire on a crew's ability to operate, extinguish the fire and or escape were assessed. A NAVAIR-led effort will test the effectiveness of advanced portable fire extinguishers on onboard fuel fires.

The vulnerability of **aircraft fuel systems** was studied by researchers from the Air Force, the U.S. Naval Air Warfare Center and Germany, with a focus on the thermal degradation of composites due to fire, skin-spar joint resistance to hydrodynamic ram pressure and hot-surface aircraft fuel ignition. This year, the group assessed composite thermal degradation and evaluated non-destructive methods to detect fire damage. The skin-spar joint resistance to the hydrodynamic ram pressure was also measured, demonstrating that the advanced joint design can withstand the intense pressures resulting from munitions penetrating an aircraft fuel tank.

In the civil aviation realm, the downing of a Malaysia Airlines Boeing 777-200ER from an altitude of 33,000 feet by a **surface-to-air missile** on July 17 in Ukraine highlights a new vulnerability of commercial aircraft to rogue missile threats. Unlike the threat of MANPADS missiles, which usually occur below 10,000 feet, the new higher-altitude threat, though rare, may expose the need for developing effective but economical countermeasures.

In addition, the earlier disappearance of another Malaysia Airlines 777-200ER while en route from Kuala Lumpur to Beijing exposed the still **poor tracking system** capability for civilian planes, which is limited to areas between control towers or 300 miles from shore over ocean waters. The FAA and its European counterpart, EASA, have considered several systems that could be developed into robust and reliable tracking tools. Some engine manufacturers, such as GE, have already been tracking their own engines for in-flight diagnosis and faster ground maintenance. Such a system could potentially help locate downed aircraft and thus provide faster rescue efforts. The Malaysia Airlines disappearance also highlights the need for longer battery life — six months instead of 30 days — and stronger deep underwater signals from the flight data recording system.

Keeping the noise down

By Jeff Peters

The ***Aeroacoustics Technical Committee*** *addresses the noise produced by the motion of fluids and bodies in the atmosphere and the responses of humans and structures to this noise.*

Aeroacoustics is a critical area in the development of aerospace products, as the demand for low noise remains important in both military and commercial applications. Controlling acoustic emissions at the source requires engineers to design for low noise from the start. Aeroacoustics research conducted in 2014 responded to this challenge, highlighted by progress made in understanding complex features in the jet plumes of tactical military aircraft and launch vehicles. Also noteworthy are recent improvements to aeroacoustic measurement systems and test facilities that provide more insight into noise source characterization of aerospace products.

An important area of research for military applications is noise reduction in **supersonic exhaust**. The objective is to mitigate noise-induced hearing loss and improve the safety of people operating near tactical aircraft. A team of engineers from Lockheed Martin, BAE Systems and the U.S. government continued the investigation of noise generated by all three variants of the **F-35 fighter aircraft**. Noise data was recorded in the near and far fields for static engine tests, conventional flight and short-takeoff/vertical-landing operations to characterize the external sound generated by the aircraft.

Noise generated by each of the three variants of the F-35 was recorded under an effort to improve the safety of people working near tactical aircraft.

U.S. Navy

Researchers at Penn State University developed a novel jet noise reduction system for **high-performance aircraft**. The patented method injects "fluidic inserts" in the diverging section of a supersonic exhaust nozzle. The inserts generate streamwise vorticity in the plume, which enhances jet mixing and reduces broadband shock-associated noise. Early experiments resulted in a 4-decibel overall sound pressure level reduction in the peak noise radiation direction using moderate amounts of bypass air to generate the inserts. Recent experiments demonstrated that the device also worked in the presence of forward flight. Larger-scale experiments are being planned at a General Electric facility, while small-scale tests and simulations continue at Penn State.

Aeroacoustics research continued to aid development of NASA's **Space Launch System** rocket. Researchers at the University of Texas at Austin teamed with colleagues from the University of Mississippi to investigate the vibro-acoustic loads that form during ignition to develop accurate predictions of the launch pad environment. A shadowgraph system synchronized with a microphone recording system provided understanding of aeroacoustic sources generated by ignition of various rocket clusters. The work was featured on Discovery Channel's "Daily Planet." At Georgia Tech Research Institute, researchers investigated the acoustic response of impulsive blast waves generated by firing a starter's pistol into subsonic and supersonic jet plumes. The acoustic measurements and flow visualizations will give insight into ignition overpressure waves generated by the SLS solid rocket booster.

Honeywell evaluated in-duct fan noise of **advanced turbofan engines** in a new open circuit rig test facility using the functional acoustic beamform method developed by Optinav Inc. The facility accommodates two phased pressure transducer arrays installed in the fan inlet and bypass ducts. The method simultaneously measures and identifies up to 50 acoustic spinning mode orders as well as radial mode orders and direction of propagation without aliasing. Mode identification agreed with Actran DGM fan noise acoustic simulations without interference from the rig.

Noise reduction, rotor research benefit from applied aero innovations

by Nathan Hariharan

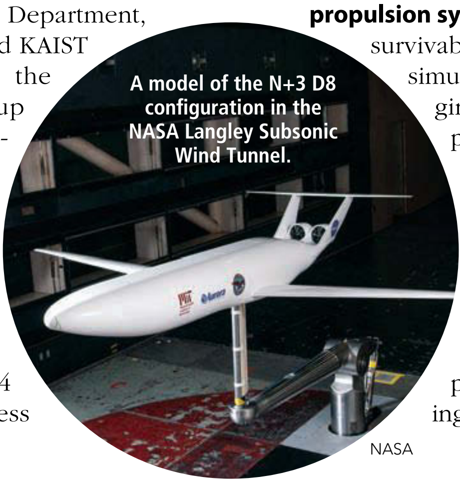
*The **Applied Aerodynamics Technical Committee** emphasizes the development, application, and evaluation of concepts and methods using theories, wind tunnel experiments and flight tests.*

NASA's efforts to develop innovative tools and techniques for analysis and design of supersonic aircraft with lower **sonic boom and airport noise** focused on nozzle flow and shock-plume interactions. Pressure measurements, schlieren images and particle imaging velocimetry data were collected for a series of nozzle and shock generator configurations in the 1-by-1-foot Supersonic Wind Tunnel at NASA's Glenn Research Center in Ohio. A revised three-stream nozzle design was tested in the Glenn Aero-Acoustic Propulsion Laboratory in cooperation with partner GE. The revised design eliminated the unsteady separation induced noise of its predecessor and validated that the noise reduction goals of NASA's next-generation N+2 supersonic community could be met.

NASA's Fixed Wing Project teamed with MIT, Aurora Flight Sciences and Pratt & Whitney to conduct experimental and computational studies to further assess the **boundary layer ingestion**, or BLI, benefit of MIT's futuristic N+3 D8 configuration. A 1/11th-scale, powered model was investigated in the 14-by-22-foot Subsonic Tunnel at NASA's Langley Research Center in Virginia. A 6-7 percent reduction in power required was shown to be produced at a simulated cruise condition when compared against a baseline, non-BLI configuration. Both force and moment data and engine inlet and exit pressure rake flow surveys were obtained to support the assessment of the BLI benefit.

The AIAA Applied Aerodynamics Technical Committee's Rotorcraft Simulation Working Group held its first hover invited session at the 2014 Annual Aerospace Sciences Meeting held during the SciTech Forum at National Harbor, Maryland. The goal of this session was to assess different approaches for the **hover prediction** of a baseline S-76 rotor planform. Georgia Tech, Sikorsky, Boeing, University of Maryland, University of Toledo, the U.S. Defense Department, University of Liverpool and KAIST of Seoul participated in the 2014 session. A follow-up session is planned for SciTech 2015, with a focus on hover performance predictions for the S-76 planform with different tip shapes.

The first **sonic boom prediction** workshop was held at SciTech 2014 with an objective to assess the state of the art in predicting sonic boom propagation. Fifty participants from 24 organizations and seven countries took part in validating their predictive simulations for a standardized configuration that was provided. Particular interest was seen in grid refinement/alignment techniques.



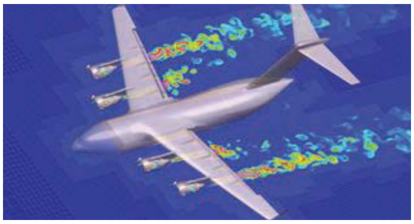
A model of the N+3 D8 configuration in the NASA Langley Subsonic Wind Tunnel.

NASA

The U.S. Defense Department's High Performance Computing Modernization Program-Computational Research and Engineering Acquisition Tools and Environments program, or **HPCMP CREATE**, continued developing and deploying scalable, multidisciplinary, physics-based computational engineering products for the design and analysis of ships, air vehicles and RF antennas.

The air vehicles program, HPCMP CREATE-AV, released two products in 2014. The fixed wing analysis tool Kestrel 5.0 introduces dual-mesh near-body unstructured and off-body Cartesian methodology for full-aircraft fixed-wing simulations such as airframe-engine integrations, tail-buffet and store-drops. The rotorcraft analysis tool Helios 5.0 introduces free-flight trim capability.

Lockheed Martin and the Air Force Research Laboratory have collaborated on the development of a **hybrid-wing body** strategic military transport, featuring over-wing integration compatible with ultra-high bypass ratio or open rotor advanced engines. The over-wing installation is 5 percent more aerodynamically efficient than an under-wing engine and the transport uses 70 percent less fuel than the legacy fleet. This performance will be validated with flight Reynolds number wind tunnel testing in the National Transonic Facility next year through an Air Force Research Laboratory/NASA partnership.



HPCMP CREATE-AV

C-17 simulation generated by the Kestrel 5.0 analysis tool.

AFRL and Lockheed Martin initiated a 3-D Navier-Stokes CFD simulation-based assessment of the integrated effect of **distributed propulsion systems** on aircraft efficiency, survivability and powered lift. The simulations include the full engine flow path with over 30 procedurally generated inlets and exhaust nozzles, an enhanced fan CFD boundary condition and shape optimizations for improved efficiency. Trade studies on nacelle length, spanwise placement and total fan propulsive area are also being conducted.

Astrodynamics enables Mars, comet exploration

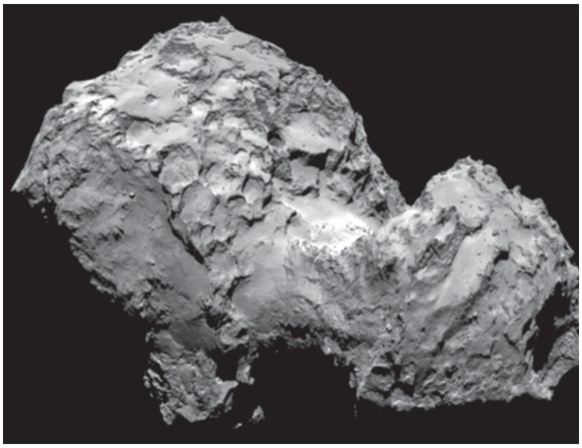
by Ryan Park

The ***Astrodynamics Technical Committee*** *advances the science of trajectory determination, prediction, and adjustment, and also spacecraft navigation and attitude determination.*

On Aug. 6, after a decade-long cruise, the European Space Agency's **Rosetta** spacecraft arrived at Comet 67P/Churyumov-Gerasimenko, making it the first spacecraft to rendezvous with a comet. Since its launch in March 2004, Rosetta performed a four-gravity assist interplanetary transfer to the comet (Earth-Mars-Earth-Earth, or EMEE), including two asteroid flybys en route. Rosetta deployed the **Philae lander** in late 2014, which searched for organic molecules on the comet's surface. Rosetta is planned to orbit the comet for about a year and will perform various in situ observations of the comet.

NASA's Mars Atmosphere and Volatile Evolution mission arrived in Mars orbit on Sept. 22. **MAVEN** will study the planet's upper atmosphere, ionosphere and interactions with the sun and the solar wind.

ESA/Rosetta/MPS



Rosetta's OSIRIS camera — the Optical, Spectroscopic and Infrared Remote Imaging System — captured this image of Comet 67P/Churyumov-Gerasimenko.

The Indian Space Research Organisation's **Mars Orbiter Mission** arrived at Mars two days after MAVEN's orbit insertion. MOM is India's first interplanetary mission as well as Asia's first spacecraft to orbit Mars. MOM showcases India's rocket launch system, spacecraft-building, and science instrument and operations capabilities.

While both spacecraft took advantage of the same Earth-Mars interplanetary transfer opportunity, MAVEN launched directly into its transfer, while MOM used a series of orbit-raising maneuvers prior to commencing the transfer.

Also at Mars, the Comet Siding Spring made an extremely close flyby of the planet on Oct. 19. With a total of five orbiters in operation at the planet, program officials had to consider precautionary measures, including orbit timing adjustments, to avoid potential damage from the comet's dust particles. Early knowledge of this flyby also provided a unique observation opportunity for all Mars assets.

China's **Chang'e 3** was launched on Dec. 1, 2013, on a Long March 3B rocket from the Xichang Satellite Launch Center in the southwestern province of Sichuan. Chang'e 3 used a direct transfer to enter a 100-kilometer-altitude circular orbit around the moon on Dec. 6, and finally landed its 1,200-kilogram lander on Mare Imbrium on Dec. 14. NASA's Lunar Atmosphere and Dust Environment Explorer, which had arrived earlier in 2013, ended its mission on April 18 by performing a controlled crash into the far side of the moon.

On May 29, two-way communication with the International Sun-Earth Explorer 3 spacecraft was re-established by the **ISEE-3 Reboot Project team of volunteer citizen-scientists**. ISEE-3, which was launched on Aug. 12, 1978, was the first spacecraft to be placed in a halo orbit at the Sun-Earth L1 point. It was renamed the International Cometary Explorer in 1982 and became the first spacecraft to fly by a comet. Although significant effort was made to place the spacecraft back into a halo orbit, the spacecraft's propulsion system had failed due to a loss of the nitrogen gas used to pressurize the fuel tanks. On Aug. 10, the spacecraft passed about 15,600 kilometers above the lunar surface. It is now in a heliocentric orbit and will return to the vicinity of Earth in 17 years.

Finally, the Seventh Global Trajectory Optimisation Competition was hosted by the Politecnico di Torino and Università di Roma "La Sapienza." The objective of the competition was for teams to design trajectories for a **mothership** (launching from Earth), as well as trajectories for three electric-propulsion daughter craft whose goal was to rendezvous with as many asteroids as possible (candidate targets included 16,000 main belt asteroids) and then rejoin the mothership. Propellant mass was the tiebreaker for solutions visiting the same number of asteroids. The winning solution came from a team from the Jet Propulsion Laboratory, with 36 asteroids.

Artist's concept of comet C/2013 A1 Siding Spring.

NASA/JPL-Caltech.

Studies target icing, lightning and electrostatic discharges

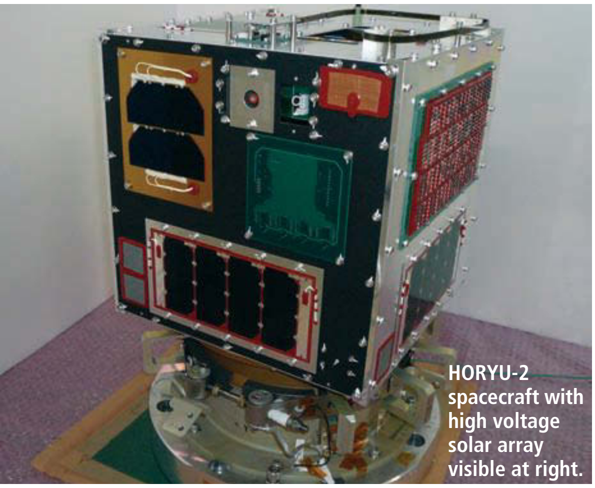
by Thomas Ratvasky, Alice Grandin, Justin Likar, William Vaughn, and Dustin Crider

*The **Atmospheric and Space Environments Technical Committee** encourages the exchange of information about the interactions between aerospace systems and their surroundings.*

Safe and successful operation of aircraft and satellites can be challenging given the complex environments in which they operate. Government, industry and academia continue to meet these challenges through significant research efforts and tool development.

During the past two decades, ice-crystal icing has caused numerous **engine power-loss** and damage events on commercial airplanes. In response, government agencies and the aviation industry are conducting research to better understand the cause and developing regulations to prevent future events. One critical task is to better understand the environment where these events occur. As such, **ice crystal clouds** associated with deep convection weather systems over northern Australia were explored from January through March through an international collaboration of 16 industry and government partners from seven countries. The European-led, High Altitude Ice Crystal and the North American-led, High Ice Water Content projects collected cloud data to characterize the ice crystal environments, develop nowcasting tools and improve the understanding of fundamental cloud physics in deep convection. In situ cloud physics and airborne remote sensing data were acquired by a well-instrumented Falcon 20 research aircraft operated by SAFIRE, the French Office of Aircraft Instrumented for Environment Research. Additionally, satellite, ground-based weather radar and lightning data were acquired to provide a comprehensive and rich data set. Ultimately, this data set will be the basis for pending regulations for engines and air data systems in order to maintain the highest level of safety on future airplanes.

In other developments, AIAA has published a **new guide**, "Terrestrial Environment Guidelines for Use in Aerospace Vehicle Development" (AIAA G-140-2014), which is available to members. The document provides natural terrestrial environment criteria guidelines for use in the design and development of aerospace vehicles traversing the terrestrial atmosphere, defined as up to 90 kilometers in altitude. It reflects on aerospace vehicle development experiences and consolidates guidelines for natural terrestrial environments that have been utilized in a large number of aerospace vehicle developments.



HORYU-2 spacecraft with high voltage solar array visible at right.

KIT

To improve lightning safety for aircraft, scientists at the University of Alabama in Huntsville are combining data from weather satellites with polarimetric radar and numerical models in a system that might warn which specific pop-up storm clouds are likely to produce lightning and when that lightning is likely to begin and end. It is hoped that **lightning warning times** can be increased from 10 minutes to as long as 45 minutes.

In orbit, multiple space flight experiments are studying phenomena relating to spacecraft charging and the effects of electrostatic discharges on space solar cells have achieved significant milestones. The **HORYU-2** High Voltage Technology Demonstration Satellite, built and operated by Kyushu Institute of Technology, achieved two years on-orbit. The satellite generated a remarkable 350 volts via a uniquely designed photovoltaic array and demonstrated electrostatic discharge detection methods on multiple solar cell layup types. HORYU-2 enabled surface potential measurements coincident with arc detection in the sun-synchronous orbit. The payload demonstrated the effectiveness of novel mitigation techniques such as films and coatings designed to reduce risk associated with spacecraft charging and discharge on solar arrays.

After achieving two years of operation on the International Space Station, the Primary Arc effect on Solar Cells At LEO, or **PASCAL**, payload was returned to Earth in May aboard a **SpaceX Dragon** capsule that splashed down in the Pacific Ocean in the SpaceX-3 mission. Conceived and developed by Lockheed Martin, the Kyushu Institute of Technology and JAXA, PASCAL observed more than 1,000 low-energy primary arcs (electrostatic discharges) on modern and legacy space solar cell types. The samples continue to undergo post-flight performance characterization and analyses. Results will provide important information regarding the damaging, cumulative effects of low-energy primary arcs occurring on cell perimeter in comparison to the better-known effects of high-energy secondary arcs occurring between adjacent cells.

A Falcon 20 operated by SAFIRE acquired in situ cloud physics and airborne remote sensing data.

NASA

Flight mechanics aims farther, higher

by Jared Grauer, Mujahid Abdulrahim, Timur Alexeev, Christopher Karlgaard, Mudassir Lone, Scott Miller and Thomas Nicoll

The ***Atmospheric Flight Mechanics Technical Committee*** *addresses the aerodynamic performance, trajectories and attitude dynamics of aircraft, spacecraft, boosters and entry vehicles.*

The Solar Impulse 2 flew for two hours and 17 minutes using stored battery power on its first flight from Payerne, Switzerland.

Solar Impulse

The Northrop Grumman **MQ-4C Triton** unmanned aircraft completed initial envelope expansion tests in March. Thirteen flights totaling 81 hours were completed, and altitudes of 59,900 feet were achieved. Only one test point out of 568 needed to be repeated. The Triton will be flown by the U.S. Navy for real-time intelligence and reconnaissance over ocean and coastal regions, maritime surveillance, and search and rescue. The first flight was on May 22, 2013.

On June 2, the **Solar Impulse 2** made its first flight, from Payerne, Switzerland, with Markus Scherdel at the controls. The Si2 is the second-generation aircraft from Solar Impulse, a project by Bertrand Piccard and Andre Borschberg to **circumnavigate the Earth** using a piloted fixed-wing aircraft under solar power. The Si2 flew for two hours and 17 minutes using stored battery power, and achieved a speed of 30 knots and an altitude of 5,500 feet.

NASA's Jet Propulsion Laboratory completed flight tests on June 28 for the **Low-Density Supersonic Decelerator** at the Navy's Pacific Missile Range Facility in Kauai, Hawaii. The LDSD is a space vehicle with a doughnut-shaped balloon that inflates around the vehicle during re-entry to generate atmospheric drag and decelerate the vehicle. For the tests, a high-altitude helium balloon carried the vehicle to 120,000 feet, where it was released and powered to Mach 4 at 180,000 feet. At Mach 3.8, the 20-foot Supersonic Inflatable Aerodynamic Decelerator slowed the vehicle to Mach 2.5 in 107 seconds. A parachute was also deployed but tore. The vehicle impacted the Pacific Ocean at between 20 and 30 mph, and all flight hardware was recovered. More tests are scheduled for 2015 and will incorporate a redesigned parachute.

The **GL-10 Greased Lightning** unmanned aircraft made its first flight in August, at NASA's Langley Research Center. The GL-10 attempts to fulfill a need for an unmanned aircraft with long endurance and a vertical takeoff and landing capability. The aircraft has 10 electric-powered propellers — eight on a wing and two on a tail that both rotate relative to the fuselage. The test included a tethered hover of the GL-10, and further tests are planned for later this year.

Lockheed Martin and NASA plan to launch the **Orion** Multi-Purpose Crew Vehicle on Exploration Flight Test-1 on Dec. 4 from Cape Canaveral Air Force Station in Florida. This is the first planned uncrewed test flight of the crew vehicle. The Orion spacecraft was designed to take astronauts past low-Earth orbit into deep space. A Delta IV heavy rocket will carry the spacecraft, where it is planned to achieve a high apogee on the second orbit and attain a high-energy re-entry of around 20,000 mph.

The GL-10 Greased Lightning unmanned aircraft.

NASA Langley

Advances in fluid dynamics

by Michael W. Plesniak and Qiqi Wang

*The **Fluid Dynamics Technical Committee** focuses on the behaviors of liquids and gases in motion, and how those behaviors can be harnessed in aerospace systems.*

Research groups at Harvard University and the University of Alabama are investigating **bioinspired propulsion**. Their recent studies examine the role of micro-structures on shark skin, which has scales, called dendrites, with a highly complex geometry that works to delay flow separation and reduce drag. Both groups also have shown that the scales have a high degree of flexibility. They are passively actuated by the shark's undulatory swimming motion, providing the necessary flow control to trigger drag reduction.

Researchers at the George Washington University are investigating the **kinematics** and **hydrodynamics** of sea lion swimming. Using markerless tracking techniques, they digitally locate the sea lion's fore flipper and track its motion throughout the propulsive "clap" stroke. This yields a mathematical description of the clap kinematics that informs a hydrodynamic study of this stroke-based form of swimming. Modified direct linear transformation codes that are typically used to track small birds and insects in flight have been employed for markerless tracking. The group is also investigating the micro-structure of sea lion fur and its potential hydrodynamic effects. Other teams of researchers at GW working in the Center for Biomimetics and Bioinspired Engineering are studying flying snakes, sea turtles and locomotion of other animals.

Caltech researchers have developed a scheme to estimate the **pressure field** from a velocity field (measured with particle image velocimetry). This is done by median polling of several integration paths through the pressure gradient field, which is calculated from the velocity field. A time series of the velocity can be used to find the unsteady pressure field, or a single velocity measurement can find quasi-steady estimation. In addition to the pressure field, the code estimates the force on a body in the flowfield, and has been shown to match experimental force measurements.

Researchers at the U.S. Naval Academy are developing tools for predicting **frictional drag** of flows over rough walls. The research focuses on determining the relevant predictive scales based solely on the roughness topography. The roughness scales that best correlate the frictional drag in the fully rough region are the root mean square roughness height and the skewness of the roughness surface elevation probability density function. The peak-to-trough roughness height is the scale that indicates when a surface will no longer behave as hydraulically smooth. Current experiments focus on the transitionally rough regime with surface roughness that has systematically changed surface parameters.

The method of "dynamic mode decomposition with inputs" was used at Princeton University to develop low-dimensional models for **flow control** applications. Rules were identified for switching between linear models constructed at several different angles of attack. Good approximations to the nonlinear lift behavior of two-dimensional pitching wings were demonstrated in wind tunnel experiments at Illinois Institute of Technology. The ability to maintain a constant lift during randomized pitching maneuvers was demonstrated. A modified version of the Goman-Khrabrov model was also shown to be effective in controlling lift hysteresis during pitching maneuvers.

The fore flipper of this California sea lion is digitally tracked during its propulsive stroke.

Megan Leftwich/GWU

Researchers at Cascade Technologies of Palo Alto, California, have developed a new numerical method, enabling the first high-fidelity simulation of fuel spray atomization in realistic engine combustors. Their method, based on a high-fidelity volume-of-fluid approach, has been validated on a fuel injector typically found in gas turbine engines. Their simulations predicted fuel spray pattern and velocity within 5 percent accuracy and spray drop-size statistics within 20 percent accuracy.

Stanford University and Cascade Technologies researchers have developed a novel wall model for large-eddy simulation of **turbulent flows**. The wall model has predicted both attached and separated flows at high Reynolds number, including a nearly stalled airfoil. Other researchers in the same organizations have used supercomputers at Argonne National Laboratory to predict the thrust and heat transfer of a **supersonic combustion ramjet** engine from the Hypersonic International Flight Research Experimentation, or HIFiRE, program. Their simulation, based on large-eddy simulation and the flamelet method, highlighted a tenuous balance between turbulent fluid dynamics and combustion at supersonic speeds. These simulations complement the flight tests in understanding the stability and operability of air-breathing hypersonic propulsion systems.

Megan Leftwich/George Washington University

Scanning electron microscope photo of the skin and fur of a California sea lion.

Ground testing spans from hypersonics to rocketry

By Ben Mills

The ***Ground Testing Technical Committee*** *focuses on evaluating aircraft, launch vehicles, spacecraft, structures, and engines in wind tunnels and other facilities.*

This year was a busy one for ground testing and saw a wide variety of test techniques being employed to meet aerospace needs.

In the hypersonic domain, a cone-shaped test article 61 inches long with a 7-degree slant angle was tested at Mach 10 inside **Wind Tunnel 9** at the Arnold Engineering and Development Complex. The goal was to reduce risk in hypersonic flight vehicle designs by improving ground test techniques for predicting flight boundary layer transition.

In the transonic area, **pressure sensitive paint** was applied to a scaled model of an **A-10** to obtain static pressure data during tests in AEDC's 16-foot transonic tunnel, known as 16T.

Also at AEDC, an Alliant Techsystems's **CASTOR 30XL** developmental rocket motor was tested in the **J-6 Large Rocket Motor Test Facility**. The upper stage rocket motor underwent final qualification static fire tests to boost the power of the Orbital Sciences Corp.'s Antares launch vehicle.

U.S. Air Force

A project engineer examines the illuminated temperature-sensitive paint coating on a 7-degree cone.

Boeing and NASA completed wind tunnel testing at AEDC's National Full-Scale Aerodynamics Complex on a full-scale **757 vertical tail model** equipped with active flow control technology. A major objective of the tests was to show that active flow control can enhance the performance of a vertical tail.

At NASA's Glenn Research Center, researchers completed Rotating Rake Improvement Testing on the Advanced Noise Control Fan rig in the Aero-Acoustic Propulsion Lab. The ANCF rig was developed to test **noise reduction** and noise measurement concepts and provide a flexible and realistic aero-acoustic source for CAA — computational aero-acoustic — code verification. At the Space Power Facility vacuum chamber at Plum Brook Station, major refurbishments to the shroud system are underway to achieve temperatures ranging from 250 degrees below zero to 150 degrees above zero to simulate the harsh environment of space.

Also, a NASA advanced **ion propulsion engine** has operated for more than 48,000 hours, or 5 and a half years, making it the longest test duration of any type of space propulsion system demonstration project. The 7-kilowatt class thruster could be used in a wide range of science missions, including deep space missions identified in NASA's Planetary Science Decadal Survey.

The 8-by-6-foot **Supersonic Wind Tunnel** at NASA Glenn has been involved in a series of tests over the past two years in support of sonic boom noise reduction goals. Also, a Mach stability test was conducted in the 8x6 SWT. During the test, a proof-of-concept experiment to implement background-oriented schlieren in the harsh environment of the 8x6 SWT was conducted.

JAXA, the Japan Aerospace Exploration Agency, conducted a demonstration test for performance seeking controls of a turbofan engine in the ground-level test facility at the Chofu Aerospace Center. The purpose of the test was to minimize specific fuel consumption. At the **High Enthalpy Shock Tunnel**, or HIEST, a wind tunnel campaign with a generic test model was conducted to determine the root cause of radiation heating effects. A simple flat plate model instrumented with coaxial thermocouples was tested at stagnation enthalpies approaching 21 megajoules per kilogram. Also in the HIEST, a new free-flight technique based on onboard instruments was successfully developed. A wind tunnel test campaign with a generic model was conducted and the technique showed that it has enough accuracy to detect the high-temperature real-gas effect on pitching-moment coefficient.

The **European Transonic Wind Tunnel** has enhanced its full-span model capabilities and productivity by improving its provisions to assess and mitigate model dynamics. ETW is testing and commissioning a new high-speed deformation measurement system to support model dynamics assessment. It is based on stereo pattern tracking using two cameras and discrete markers. New cameras allow a tracking frequency of up to 386 hertz. Due to the relatively high sampling frequency and a target resolution of 0.1 millimeter in bend and 0.1 degree in twist, it will be well suited to identify relevant aeroelastic oscillations.

New control, tracking needs identified

by Leena Singh and Luisella Giulicchi

*The **Guidance, Navigation, and Control Technical Committee** advances techniques, devices, and systems for guiding and commanding flight vehicles.*

The **X-56A** Multi-Utility Technology Testbed, a modular, unmanned research flight vehicle designed to advance aeroelastic control technologies, continued a series of test flights at the NASA Armstrong Flight Research Center in California. Technologies being investigated include active **flutter suppression** and **gust load mitigation** in thin, light, high-aspect-ratio wings that are considered crucial to the future of long-range aircraft. With two center bodies, a set of stiff wings and three sets of flexible wings, the X-56A system exhibits multiple rigid-body and aeroelastic instabilities within its designed flight envelope. It is being tested in flight regimes that excite these instabilities to demonstrate that onboard instrumentation can not only accurately predict and sense the onset of wing flutter, but that an onboard controller can actively suppress aeroelastic instabilities.

On March 8, Malaysia Airlines flight **MH370** departed Kuala Lumpur en route to Beijing, checked in normally with ground stations with its autonomous Aircraft Communications Addressing and Reporting System for 26 minutes after takeoff and via cockpit voice systems with Malaysian Air Traffic Control until handover to Vietnamese airspace, and then disappeared from contact. The aircraft's ACARS was silenced, missing its next anticipated transmission windows, and neither the cockpit crew nor the plane's transponder units checked in with Vietnamese ATC and radar systems. Malaysian military radar logs subsequently placed the aircraft in unexpected flight points over the Andaman Sea — well west of its last transponder-reported location and far from its anticipated route. An Inmarsat satellite received hourly full or partial handshake signals from the aircraft's ACARS unit for six hours after the military radar sighting, thus allowing a reconstruction of the path the plane might have flown and where it might have come down. Oceanic search corridors were then defined on the strength of these predictions. No trace of the aircraft has been detected to date.

The disappearance of MH370 highlights the fact that there is no standing system for airlines and ATCs to track planes over the world's ocean and desert regions. The International Civil Aviation Organization convened a meeting of specialists and experts in Montreal in May with the goal of defining a system that would obviate **radar "dead zones"** and provide tamper-proof coverage that cannot be disabled mid-flight while not adding risk to aircraft safety protocols. The working group is expected to converge on a design that leverages and works with the anticipated global ATC upgrade systems.

Sentinel-1A, the European Radar Observatory, was launched in April and is fully operational. Designed and developed by the European Space Agency and funded by the European Commission, Sentinel-1A represents the first space component of the ambitious and unique Copernicus program, which aims to provide continuous operational Earth observation data and services. The mission survived an extremely risky **collision-avoidance maneuver** during separation from the Soyuz launcher, before the spacecraft's GNC capacities were fully deployed. The potential encounter with an unmaneuverable NASA satellite outlined the risk posed by the high concentration of debris at low-Earth orbit altitude, around 600 kilometers.

Sentinel-1A, the European Radar Observatory, was launched in April.

ESA

Orbital Sciences Corp.'s **Cygnus** cargo carrier spacecraft lifted off twice this year, in January and July, on month-long missions to the International Space Station on the Antares launch vehicle. A third mission in October failed when the Antares rocket exploded shortly after liftoff.

Cygnus uses its on-board thrusters to raise its orbit to rendezvous and berth with ISS. Cygnus delivered supplies to the station and departed loaded with unneeded trash, then fell harmlessly over an uninhabited area of the South Pacific Ocean. These missions were the first of eight planned commercial cargo resupply missions to the ISS under the NASA Commercial Resupply Services contract to deliver up to 20,000 kilograms of supplies to the station.

A year of enhancements, plus a ground-breaking vision document

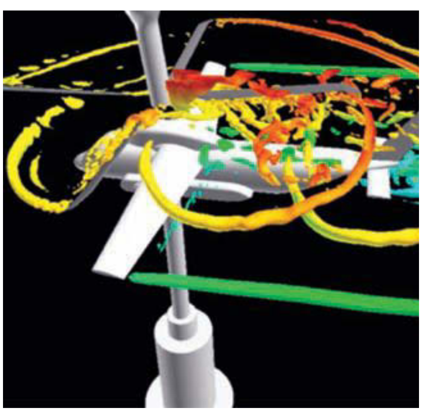
By James Masters

The ***Meshing, Visualization, and Computational Environments (MVCE) Technical Committee*** *explores the application of computer science to pre-processing, post-processing, and infrastructure in support of computational simulation in the aerospace community.*

Government, academia and industry innovated in 2014 often by applying synergetic relationships.

Personnel from Utah State University worked with NASA and the U.S. Army to continue work on **strand meshing** and to develop efficient solution methods for strand grid applications. Significant improvement was seen in the convergence of test cases using a new multigrid algorithm, and a new discretization strategy was introduced to better tolerate mesh skewness induced by strand smoothing.

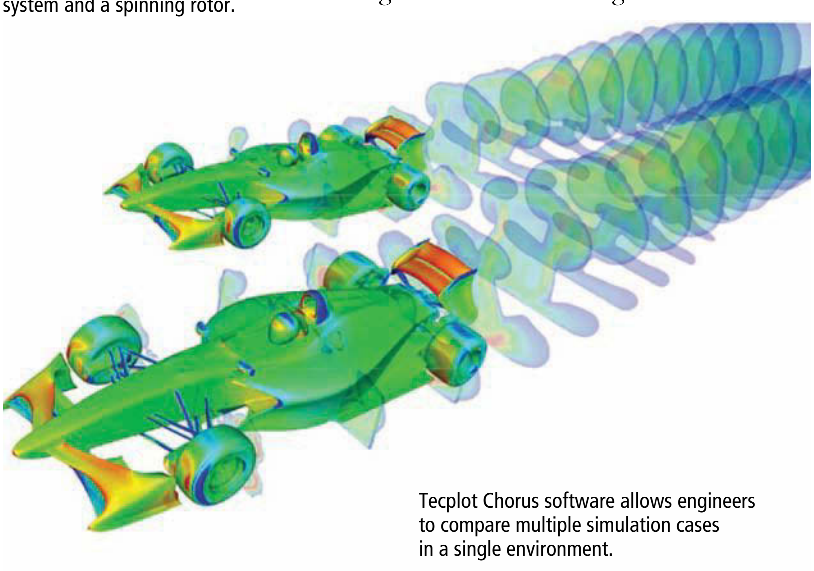
Pointwise Inc., working with the U.S. Air Force, added the ability to set up, execute, and visualize an **overset grid assembly**. Overset meshing remains an industry-standard method for analyzing bodies moving in proximity to one another. Also on the mesh generation front, several advancements were made to Capstone, developed under the Department of Defense's Computational Research and Engineering Acquisition Tools and Environments or CREATE program, including improved repair of geometries, modeling of multi-body configurations using an overset approach and automated generation of boundary-layer meshes, including sliding-planes for moving parts.



David Kao/AIAA Journal

Clipped iso-surfaces are colored to highlight vortices from the geometric components of a compound helicopter — an aircraft with a wing/tail lifting system and a spinning rotor.

In the **visualization** arena, Intelligent Light continued to evolve its flagship product Fieldview to adapt to the computational fluid dynamics trend of utilizing ever-growing datasets by allowing parallel post-processing and visualization, providing tools to isolate surfaces without having to access the larger volume data and by incorporating VisIt, which provides a scalable infrastructure for parallel analysis and visualization. Likewise, visualization issues were also addressed with Tecplot's new Chorus tool to compare multiple simulation cases in a single environment.



Tecplot Chorus software allows engineers to compare multiple simulation cases in a single environment.

Tecplot

Work was performed at the Arnold Engineering Development Complex to improve a framework for control and communication between multiple software packages for **multidisciplinary simulations**. Though quite flexible and widely used for complex store separation simulations using CFD, the framework's underlying methodology led to inefficient operation for extremely complex or long-duration simulations. A new method was developed that employs a client-server approach allowing more efficient operation and memory-based storage.

Also in 2014, the aerodynamic phenomenon of **vortex interactions** in helicopter rotor wakes was widely investigated. These wakes are visualized using enhanced flow visualization techniques and in turn play a crucial role in understanding the dynamics of these complex flows. A paper on this topic, "Visualization and Analysis of Vortex Features in Helicopter Rotor Wakes" (AIAA-2013-1162), was this year's recipient of the AIAA MVCE Technical Committee's Shahyar Pirzadeh Best Paper Award. Research presented in this paper demonstrated iso-surfaces clipped in a 3-D volume to reduce visual clutter and flow textures used to highlight vortical flow structure and vortex-wake interactions.

A focal point of CFD thought was published this year, "CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences." This study identified seven anchors that contribute to the recently perceived **stagnation of CFD** capability advancement that may prevent CFD from timely movement along the trajectory required to deliver revolutionary capabilities by 2030. Three of the seven anchors pertain to MVCE: mesh generation as an onerous bottleneck, the burden of extracting engineering data from large numbers of large datasets, and the challenge of standardizing the exchange of data within multidisciplinary frameworks.

These issues are being addressed by many organizations taking different paths to lessen the burden on the engineering analyst. The MVCE community remains committed to continue tracking the progress of the technologies within the scope of its mission and using its resources to influence the trajectory of their development.

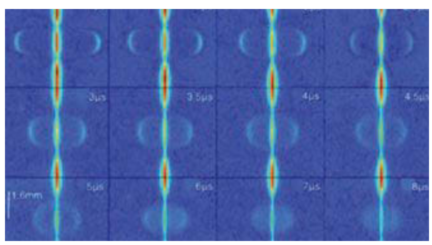
Studies explore new plamsa applications

by Michael D. White and Timothy J. Madden

*The **Plasmadynamics and Lasers Technical Committee** works to apply the physical properties and dynamic behavior of plasmas to aeronautics, astronautics and energy.*

The year brought important strides in plasma-enhanced combustion, new diagnostic techniques, flow control and laser physics. An AIAA discussion group made up of members of academia, industry and government also culminated a multiyear effort by producing a forward-looking white paper, "Plasma Aerodynamics: Current Status and Future Directions."

Significant progress has been made in the non-equilibrium plasma kinetic mechanisms for **plasma-assisted combustion** through the Multidisciplinary Research Program of the University Research Initiative sponsored by the Air Force Office of Scientific Research. Researchers from Ohio State, Princeton University, Pennsylvania State and Georgia Tech have developed and validated detailed combustion kinetic models for hydrocarbon fuels, and have developed new diagnostic techniques for high pressure combustion environments.



Princeton University

Hyperspectral Thomson scattering profiles of laser spark evolution, together with Rayleigh scattering from the surrounding air, yields the spatial profile of the time-evolving electron temperature and density.

A study undertaken by researchers from the École Polytechnique, Moscow State University and the University of Michigan looked at **superfast energy transfer** from the electric field to gas heating. The study showed that fast ionization waves can lead to high energy density and fast gas heating due to electronic relaxation, with atomic oxygen playing a key role in the process.

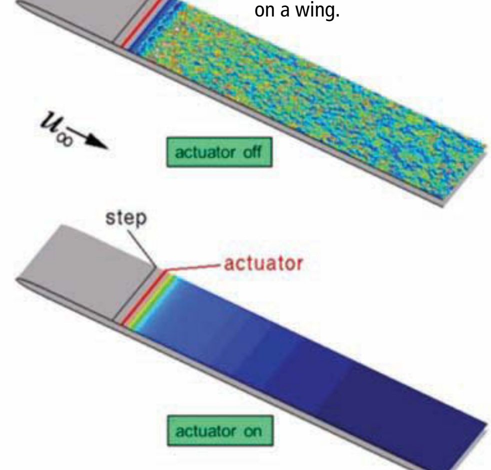
Researchers at the Air Force Research Laboratory have carried out numerical simulations to explore **plasma-based flow control** on geometries that were representative of panel gaps on wing sections that disrupt laminar flow, thereby increasing skin friction and drag. Dielectric barrier discharge plasma actuators were employed to delay transition and it was shown that the integrated drag of the configuration could be significantly reduced.

A new method has been developed at Princeton for quantifying **localized plasma evolution** based on Rayleigh, depolarized Rayleigh, Filtered Rayleigh and Thomson scattering. Simultaneous images of these scattering phenomena taken through the plasma, and referenced to scattering from the surrounding unperturbed air, to provide spatially resolved, quantitative measurements of density, dissociation fraction, electron temperature and density, shock wave velocity and other time-evolving quantities.

Laser development has been very active, particularly within military demonstration programs. Laser technology programs have shown progress toward demonstrating the viability of lasers as weapon systems. The Air Force Research Laboratory's Directed Energy Directorate and the Defense Advanced Research Projects Agency are developing the Demonstrator Laser Weapon System based on the General Atomics distributed gain solid-state laser technology previously developed with DARPA funding. The Defense Department High Energy Laser Joint Technology Office Robust Electric Laser Initiative demonstrated fiber and solid state laser technologies that have been expanded into programs within the services. The Army is developing a ground-based defense system and the Navy a helicopter-based system, both derived from the Robust Electric Laser Initiative. Separately, DARPA and the Missile Defense Agency have fiber laser system development programs intended to demonstrate the ability to combine many separate fiber laser amplifiers with high beam quality. The underlying theme across these programs is the demonstration of high power with Airborne Aero-Optics Laboratory good beam quality.

Within the arena of **aero-effects**, the Airborne Aero-Optics Laboratory-Transonic program at the University of Notre Dame, funded by the Defense Department's laser office and AFRL's Directed Energy Directorate, began flight testing turret configurations on a Falcon 10 aircraft donated by Notre Dame benefactor Matthew G. McDevitt. These tests are collecting wavefront data for Mach 0.8 and above, bringing more transonic phenomenon such as weak shocks into consideration for the aero-effects problem than were addressed in the earlier AAOL program. These flight tests will allow test data to be collected for various turret configurations, assessing applicability within the transonic flight regime. Elsewhere AFRL is pushing aero-effects investigation further into the compressible regime, performing turret boundary layer characterization experiments at the Trisonic Gasdynamic Facility located at AFRL's Aerospace Systems Directorate in Dayton, Ohio.

Effect of a plasma actuator on a rearward facing step used to model a panel mismatch on a wing.



Air Force Research Laboratory

Large- and small-scale developments in thermophysics

by Andrew Williams and Derek Hengeeld

*The **Thermophysics Technical Committee** promotes the study and application of mechanisms involved in thermal energy transfer and storage in gases, liquids and solids, or combinations.*

This year brought both large- and small-scale developments in the field of thermophysics. In July, the **sunshield** for NASA's **James Webb Space Telescope** completed its first deployment test at a Northrop Grumman facility in Redondo Beach, California. The five-layer sunshield, unfolded to a final size of 12-by-18 meters, protects the telescope from solar heating and passively cools infrared science instruments to 45 kelvins. It also separates the warm and cold sides of the telescope to provide a thermally stable environment for precise alignment of the telescope's 18 primary mirrors.

To support development of the Webb telescope, NASA Goddard Space Flight Center's Cryogenics and Fluids Branch implemented a new approach for measuring total hemispheric emissivity of **thermal coatings** at cryogenic temperatures. The technique, carried out in a 10-kelvin cryostat, simulates radiative heat exchange between parallel plates and provides an emissivity measurement with better than 1 percent precision for temperatures between 300 and 20 kelvins. Using this approach, engineers characterized several candidate surface treatments for radiator surfaces and for absorbers to reduce stray thermal radiation in the region of the telescope's detectors. Once launched, the Webb telescope will be the most powerful sent to space and will provide scientists an unprecedented ability to detect distant objects and to look back in time at the origins of the universe.

On a much smaller scale, **oscillating heat pipes**, or OHPs, an emerging passive thermal control technology, took a major step forward to commercialization. ThermAvant Technologies, in collaboration with the Air Force Research Laboratory Space Vehicles Directorate, developed and tested a rapid, lower-cost manufacturing method for a high thermal conductivity OHP heat spreader. Costing a fraction to produce compared with traditional technologies, the measured thermal conductivity for the 0.08-inch-thick heat spreader was greater than 1,500 watts per meter kelvin, which is nine times greater than aluminum.

An OHP consists of a capillary-sized serpentine channel partially filled with a working fluid, such as the refrigerant R-134a. Evaporation and condensation of the fluid between hot and cold sections of the device create a pressure imbalance that causes fluid oscillations through the length of the channels. Rapid oscillation quickly and efficiently transports heat away from hot components, such as high power processors and power amplifiers. Because OHPs consist of millimeter-size channels, they are easily scaled to a wide range of patterns and device sizes.

Also in the area of two-phase thermal transport, researchers at UCLA recently developed and tested an inorganic aqueous solution that is compatible with aluminum and steel phase change heat-transfer devices. Bench-top lifetime testing showed minimal gas generation after 10 weeks for devices filled with the solution. Conversely, similar devices filled with water failed within minutes of start-up.

Water is one of the best heat-transfer fluids for phase change devices, but it has limited use in aerospace systems because it reacts with some metals to create non-condensable gases, which cause performance degradation and eventual device failure in phase change heat transfer devices. UCLA's novel solution simultaneously inhibited the creation of NCGs and significantly increased heat-transfer performance by creating a hydrophilic microstructure on the metallic surface.

Finally, this year AFRL's **Active Thermal Tile** experiment completed operation aboard the International Space Station. ATTs are variable conductance thermal interface gaskets that use thermoelectric devices to modulate heat transfer between a component and a spacecraft structure. Developed by AFRL/RV in conjunction with the Department of Defense Space Test Program and Infoscitex Corp., the devices control component temperatures within 0.1 kelvin despite spacecraft temperature fluctuations. This is especially useful for components with tight temperature requirements such as batteries, sensors and clocks.

Northrop Grumman engineers stack and unfurl a full-sized test unit of the sunshield for NASA's James Webb Space Telescope.

NASA

Advances in aerodynamic deceleration

by Jean Potvin and Lauren S. Shook

The ***Aerodynamic Decelerator Systems Technical Committee*** *focuses on decelerating manned and unmanned vehicles via parachutes, pararotors, and inflatable decelerators.*

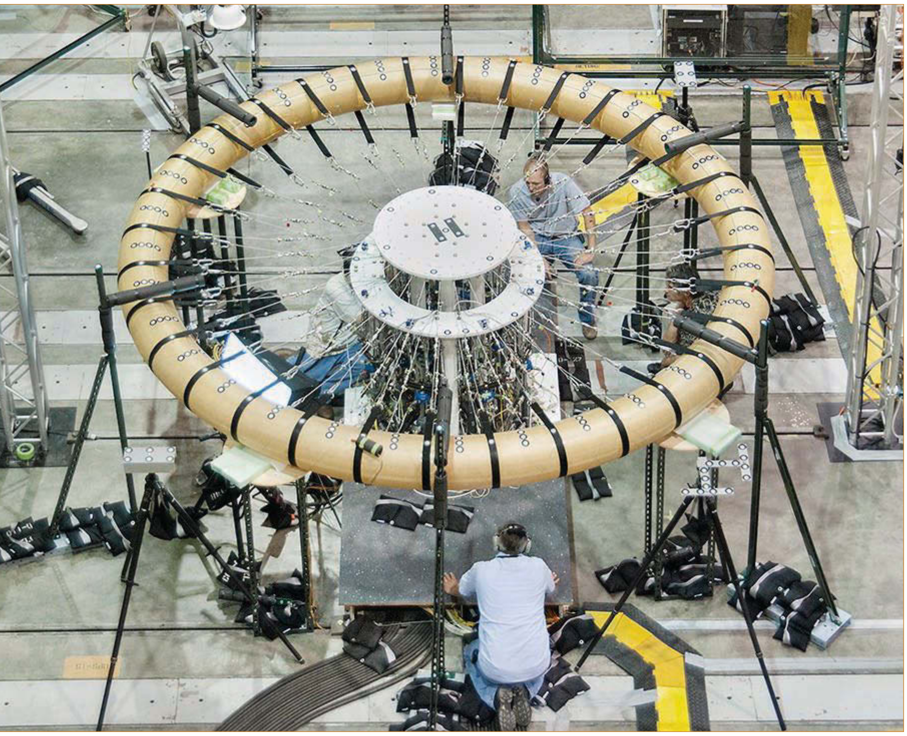
Development testing of Orion's **Capsule Parachute Assembly System** is nearly complete in anticipation of a critical design review in 2015. Highlights from the past year included two end-to-end tests in which the forward bay cover was jettisoned from the boiler plate before CPAS deployment. Testing was conducted in coordination with the Army Yuma Proving Ground in Arizona and the Air Force Material Command's 412th Test Wing. The CPAS team has also demonstrated the test capability to implement the low-velocity air drop technique from 35,000 feet mean sea level. This provides the ability to test at the nominal Orion deployment point for spacecraft entry from space. In addition, CPAS was integrated into the Orion Exploration Flight Test-1 capsule, scheduled for December.

The Army has placed an emphasis on maximizing the accuracy, reliability and survivability of autonomously guided cargo airdrops while minimizing cost; size, weight and power requirements; and component retrograde. The Natick Soldier Research, Development and Engineering Center has been developing guidance, navigation and control algorithms that employ visual data for use in GPS-denied or -degraded regions, avionics components and sensor networks, advanced wind measurement techniques, and autonomously actuated canopy vents for latitudinal and longitudinal system control. In addition, Natick and its partners fielded a **High Speed Container Delivery System**, which was first used in Afghanistan. The HSCDS can airdrop eight CDSs (up to 16,000 pounds) from an altitude of 250 feet at 250 knots indicated airspeed. That is significantly lower and faster than typical CDS airdrops of 500 feet and 140 knots, and will improve the survivability of aircraft and crews while providing a tighter dispersion and increased accuracy.

The Jet Propulsion Laboratory's **Low-Density Supersonic Decelerator** project, part of the Space Mission Technology Directorate, conducted the first high-altitude, supersonic flight tests of the next generation of aerodynamic decelerators for **future Mars missions**. Primarily a shake-out flight, the test lofted a 4.7-meter blunt-body aeroshell to an altitude of over 30 kilometers using a 34-million-cubic-foot balloon. The test vehicle was released from the balloon and accelerated to above Mach 4 and an altitude of 54 kilometers, where a 6-meter-diameter Supersonic Inflatable Aerodynamic Decelerator was deployed and used to slow the vehicle. The flight also saw the deployment and inflation of a large 4.4-meter-diameter trailing ballute at approximately Mach 2.7. A supersonic parachute was also deployed but was severely damaged during supersonic inflation.

NASA's Langley Research Center has also been working on the **Hypersonic Inflatable Aerodynamic Decelerator** project. An integrated 10-meter-class static load test was completed on the flexible thermal protection system, or F-TPS, integrated with the inflatable structure. Instrumentation checks were done for strap load cells and foil gauges. The team used instrumentation to measure the load carried by the F-TPS. Preliminary results indicated the F-TPS is carrying approximately 25 percent of the total load. Tests were conducted using a variety of inflation pressures and load cases.

NASA's Ames Research Center completed Arc Jet testing of woven carbon fabric joints for the Adaptable, Deployable Entry Placement Technology program. **ADEPT** is a mechanically deployable semi-rigid aeroshell entry system. Two-inch-wide joints were tested at 100 watts per square centimeter over a two-minute duration under a 100 pound-force per inch load. Both the carbon stitching and the carbon gore fabric survived the test. A resin-infused joint tested was found to be more resistant to layer loss. Additionally, there was excellent validation of pre-test CFD predictions with the Arc Jet test observations. ▲



Technicians prepare the Hypersonic Inflatable Aerodynamic Decelerator for structural loads testing in the Flight Loads Laboratory at NASA's Armstrong Flight Research Center.

NASA

Design pushes the innovation envelope

by Dyna Benchergui and Charlie Svoboda

The ***Aircraft Design Technical Committee*** *promotes optimization of aircraft systems, including analysis of their future potential.*

JLENS uses radar to detect, track, and target missiles and aircraft.

U.S. Army

The Navy and Northrop Grumman completed testing of the autonomous **X-47B** Unmanned Combat Air System Demonstrator aboard the aircraft carrier Theodore Roosevelt in August, showing the airplane's ability to operate alongside manned naval aircraft. Demonstrations included launches and recoveries alongside F/A-18 fighter jets, wing-fold and tailhook retraction system testing, jet blast deflector testing, flight deck night operations and flying qualities evaluation.

The Naval Research Laboratory demonstrated its first **stealthy launch** of an unmanned aerial vehicle from a submerged submarine. Developed in under six years, the all-electric fuel cell powered folding wing Sea Robin Experimental Fuel Cell aircraft was fired from the submarine torpedo tube.

The Navy completed initial flight testing of the Northrop Grumman-developed **MQ-4C Triton**, a maritime version of the Global Hawk high-altitude unmanned aircraft. The Navy also established a Triton training center and the first operational squadron. Initial deployment is planned for 2017.

Under DARPA's **Aerial Reconfigurable Embedded System** program, Lockheed Martin Skunk Works and Piasecki Aircraft completed detail design of a twin ducted fan, modular vertical takeoff and landing unmanned airplane and are proceeding with fabrication and flight testing in 2015. The aircraft will demonstrate VTOL, transition, and cruise flight with and without a modular cargo payload.

The Army is completing operational evaluation of Raytheon's Joint Land Attack Cruise Missile Defense Elevated Netted Sensor aerostat system — known as **JLENS** — following completion of system design in December 2013. Designed to detect and track missiles and aircraft, JLENS consists of two tethered airships floating at 10,000 feet to provide radar coverage over an area the size of Texas.

In manned aircraft developments, the Air Force released the final request for proposals for its high-priority **Long Range Strike Bomber**, which will replace the B1-B, B-2 and B-52 fleets. The **F-35 Joint Strike Fighter** program continued flight test progress, including weapons separation and software compatibility. The fleet surpassed 19,500 flight hours. Under its Maritime Surveillance Aircraft program, Boeing finished modifying a Bombardier Challenger 605 to carry mission systems from the P-8A Poseidon, achieving first flight in February.

The **Airbus A320neo** (new engine option) completed its first flight, and the A350-900 remained on schedule to receive EASA type certification. Boeing's 787-9 achieved FAA type certification and the 787-10, the largest 787 so far, completed firm configuration milestone. Bombardier's Challenger 350, Learjet 70, and Learjet 75 received full type certification and the Learjet 85 began flight testing. Cessna's Citation CJ3+ received FAA type certification.

The X-47B Unmanned Combat Air System Demonstrator conducts flight operations aboard the carrier Theodore Roosevelt.

U.S. Navy

Examining flight statistics

by Karen Marais
*The **Aircraft Operations Technical Committee** promotes safe and efficient flights in the airspace system by encouraging information sharing among the community and government agencies.*

U.S. air transportation operations continued their gradual rebound from the economic collapse of 2009. **Domestic passenger enplanements** increased from 698,813 in May 2012 to 705,398 in May 2013, according to Transportation Department statistics released in 2014. The trend was different in Europe, where statistics from the **European Union** show passenger arrivals and departures decreasing from 826,463,402 in 2012 to 632,490,533 in 2013, as airlines chase an elusive recovery.

Jet fuel prices continued to drop around the world. The price in October 2014 was on average 17 percent lower than the price in October 2013, according to the International Air Transport Association. Combined with higher load factors and higher overall traffic, most carriers showed good financial results and were rewarded by the stock markets. However, low cargo revenues and rising costs for Chinese carriers weighed on regional financial performance in the Asia-Pacific region, according to IATA.

RMG Petroleum

Jet fuel prices in October 2014 were on average 17 percent lower than in October 2013.

In April, Wichita State and Embry-Riddle universities released their annual Airline Quality Rating. Based on 2013 data, they gave the U.S. airline industry its **best overall performance ratings** to date. Although only 78.4 percent of flights arrived on time compared to 81.8 percent in 2012, and incidents of baggage mishandling increased from 3.07 per 1,000 passengers in 2012 to 3.21 per 1,000 passengers in 2013, airlines received fewer customer complaints: 1.13 per 100,000 passengers in 2013 versus 1.43 per 100,000 passengers in 2012. In addition, fewer passengers were denied boarding, with data showing a decline from 0.97 denials per 10,000 passengers in 2012 to 0.81 per 10,000 passengers in 2013. The downward trend in on-time arrivals is worrisome, especially as traffic levels continue to pick up.

When it comes to **safety**, 2014 saw several large aircraft accidents. In March, Malaysia Airlines flight 370 disappeared somewhere over the Pacific with 239 people aboard. July was a particularly tragic month. An Air Algerie flight crashed in Mali, killing all 116 occupants; a TransAsia Airways plane crashed in Taiwan, killing 48 of the 58 occupants; and Malaysia Airlines flight 17 was shot down over Ukraine, killing all 298 on board. Although the death toll for 2014 will be at least double that of 2013 (265 fatalities), overall commercial aviation continues to be remarkably safe, especially in North America and Europe, according to statistics from the Flight Safety Foundation's Aviation Safety Network.

In air traffic control developments, a disgruntled employee started a fire at an **Air Traffic Control Facility** in Aurora, Illinois, in October. Thousands of flights across the United States were cancelled over several days while controllers at other centers stood in for the disabled Aurora center. While the air traffic control system maintained safety, this unprecedented event revealed an unexpected risk to air traffic operations.

Operations continue to be a popular research topic, with more than 20 sessions covering operations at AIAA's Aviation 2014 Forum in Atlanta in June. Research continued on topics related to air traffic control across all flight phases. Unmanned aerial systems and how they could be integrated into the airspace are gaining increasing attention. Electric propulsion also continues to be a topic of interest.

Better tracking and management

by David Thipphavong, Joseph Post and Jesper Bronsvoort

*The **Air Transportation Systems Technical Committee** fosters improvements to transport systems and studies the impacts of new aerospace technologies.*

The global airline industry continued to grow in 2014, with profits projected to expand from $12.9 billion in 2013 to $18.7 billion by the end of this year. Key factors driving this increase include continued improvement in overall economic conditions, greater air cargo volumes and stable fuel prices. However, the razor-thin profit margin of 2.5 percent is susceptible to various risks, including the possibility of higher fuel prices due to political crises around the world. In addition, new orders for Airbus and Boeing aircraft are expected to be half of the nearly 3,000 ordered in 2013.

Australia saw the world's first **Automatic Dependent Surveillance-Broadcast** mandates come into effect. ADS-B is a satellite-based technology that enables aircraft to be accurately and reliably tracked by air traffic controllers and other pilots without conventional radar. Australia's network of 61 ADS-B ground stations improves operational efficiency, especially in non-radar airspace that comprises the majority of continental Australia. ADS-B is now required for aircraft flying at or above 29,000 feet in Australian airspace. Furthermore, all new aircraft registrations must be ADS-B capable to operate under instrument flight rules.

In the United States, the integration and implementation of **NextGen** technologies, concepts and procedures continues. The deployment of the 634 ground stations that comprise the nation's ADS-B ground infrastructure was completed in March. In addition, the En Route Automation Modernization system that enables many NextGen capabilities is planned to be fully operational at all 20 centers in the National Airspace System by mid-2015.

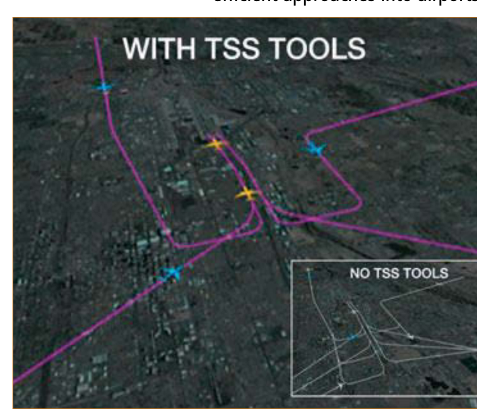
A Puma unmanned aircraft is retrieved after demonstrating its potential to detect oil spills in the Arctic.

NOAA

NASA has been collaborating with the FAA and industry partners to develop advanced automation tools to enable safer, more reliable and more efficient arrival operations. In July, NASA transferred to the FAA its **Terminal Sequencing and Spacing** tool. TSS will help air traffic controllers manage the spacing between aircraft as they perform more efficient, performance-based navigation arrival procedures. TSS was validated in a series of large-scale, high-fidelity, human-in-the-loop simulations performed jointly by NASA, FAA and MITRE's Center for Advanced Aviation System Development.

This year saw significant attention toward **unmanned aircraft** operations in the National Airspace System. The FAA approved all six proposed test sites, which are conducting two-year research programs to collect data on technologies and operations required to safely integrate unmanned aircraft into the NAS. Separately, a group of government and industry partners is working under the Radio Technical Commission for Aeronautics to develop performance standards for detect-and-avoid systems and command-and-control datalinks for larger unmanned aircraft flying outside of busy terminal areas expected by July. In addition, the long-awaited draft rule for small unmanned aircraft operations should be released by the end of 2014. Lastly, the first approved private, domestic, commercial unmanned aircraft are now operating in specially designated areas of the Arctic.

NASA's Terminal Sequencing and Spacing tool enables more efficient approaches into airports.



NASA

In March, **Malaysia Airlines flight 370** vanished en route from Kuala Lumpur to Beijing. An analysis by British satellite telecommunications company Inmarsat, corroborated by various international organizations, concluded that the Boeing 777 turned west and then south. Its fate remains a mystery as the search continues in the southern Indian Ocean. The disappearance of such a large aircraft without a trace is unprecedented, and an international effort is underway to mandate that all airline flights be tracked continuously regardless of their location. Meanwhile, starting in 2015, Virginia-based **Iridium** Communications will launch a new constellation of communications satellites with ADS-B receivers that will enable tracking of ADS-B-equipped aircraft in oceanic airspace.

Testing manned, unmanned and space systems

by Jay Brandon

*The **Flight Testing Technical Committee** focuses on testing of aircraft, spacecraft, missiles or other vehicles in their natural environments.*


Scorpion fighter jet.

Textron AirLand

Focus continued to increase this year on the testing of unmanned aircraft systems, with the FAA announcing the selection of six operators of **unmanned aircraft test sites**.

The test site operators are the University of Alaska (including ranges in Hawaii and Oregon), the state of Nevada, Griffiss International Airport in New York (including ranges in Massachusetts), the North Dakota Chamber of Commerce, Texas A&M University-Corpus Christi, and Virginia Tech (including ranges in New Jersey).

The Northrop Grumman **X-47B** Unmanned Combat Air System demonstrator was launched from an aircraft carrier in August and operated alongside an F/A-18E above the Atlantic Ocean, demonstrating the first integration of carrier-based drones and manned fighter jets. **Phantom Eye**, a Boeing-designed hydrogen-powered unmanned demonstrator for high-altitude, long-duration flight, completed its seventh and eighth flights and has now demonstrated flight endurance of more than 5½ hours and altitudes greater than 43,000 feet.

Sikorsky's **Optionally Piloted Black Hawk** Demonstrator performed autonomous hover and flight operations on March 11 in a step toward providing the U.S. Army with an autonomous cargo delivery capability.

In manned aircraft highlights, the Bombardier **Learjet 85** business jet completed its first flight on April 9, flying over two hours at altitudes up to 30,000 feet and speeds up to 250 knots. The Textron AirLand **Scorpion**, a demonstration aircraft developed as a low-cost tactical jet option for low-threat missions, conducted its first flight on Dec. 12, 2013. The Scorpion progressed from initial design to first flight in less than 24 months.

The Lockheed Martin **F-35B**, the short-takeoff/vertical-landing variant of the new fighter, demonstrated air-to-air combat capability on May 27 with the sequential engagement of two aerial targets with two AIM-120 advanced medium-range air-to-air missiles — the first dual-AMRAAM shot from any F-35 variant. The F-35B also completed wet runway testing. And on May 27, an F-35C, the aircraft carrier variant, completed landing tests at maximum sink-speeds, demonstrating the structural readiness for tests at sea. Ground collision avoidance systems were tested on the F-16, F-22A and F-35.

NASA, the German Aerospace Center and the National Research Council of Canada participated in tests of the effects of **renewable fuels** on the environment. A NASA HU-25C Falcon, a German Falcon 20-E5, and a Canadian CT-133 trailed a NASA DC-8 burning various blends of JP-8 and renewable alternative fuels to observe and measure emissions and contrail characteristics.

The application of modern design of experiments techniques to many projects resulted in vastly improved efficiencies, and a near-real-time six-degrees-of-freedom nonlinear aerodynamic modeling capability was demonstrated on a test jet aircraft during a joint NASA-National Test Pilot School project. The test provided **real-time maneuver guidance** to the pilot and resulted in global nonlinear aerodynamic models, developed and validated over a full flight envelope, all completed before landing on a single flight.

In space-related tests, the **Morpheus Lander**, a NASA project that uses nontoxic propellants — methane and oxygen — performed a nighttime landing in May during which objects in a hazard field where automatically avoided.

A NASA F/A-18 research aircraft was used to evaluate the autonomous flight control system being developed for the Space Launch System rocket. SLS-like trajectories were flown while using the **Adaptive Augmenting Controller**, designed to allow the SLS to respond to winds and vehicle flexibility.


The X-47B drone and a manned F/A-18E Super Hornet side by side on the Theodore Roosevelt.

U.S. Navy

New life for lighter-than-air systems

by Norman Mayer

*The **Lighter-Than-Air-Systems Technical Committee** stimulates development of knowledge related to airships and aerostats for use in a host of applications from transportation to surveillance.*

Hybrid Air Vehicles in the U.K. began reassembling the former Long Endurance Multi-intelligence Vehicle, the airship it bought back from the U.S. Department of Defense in 2013 following the project's cancellation. HAV had originally worked on designing and building LEMV on a team led by Northrop Grumman. After purchasing the airship, the company received a £2.5 million ($4 million) grant from the U.K. government's Technology Strategy Board to work on further engineering development of a heavy-lift variant of the craft. The new version, named **HAV 304**, is being built from LEMV's components and will have an empty payload module. For its first few months of flight the HAV 304 will be considered a civil craft, pending a government decision on whether to approve that designation. U.K. Civil Aviation Authority flight trials are expected to end in April. Scheduled flights include one to North America in October 2015, to demonstrate the airship's commercial potential, and other flights to destinations of military interest.

The **Spirit of Goodyear** airship was decommissioned after 14 years of aerial advertising and was recognized by Guinness World Records for being the "longest continuously operating airship." The blimp was moored outside the Wingfoot Lake hangar in Ohio to make room for assembly of the new Zeppelin NT German semi-rigid airship. The decommissioned blimp was then flown to Goodyear's Florida base in Pompano Beach.

Russia's Augur RosAeroSystems showed renewed interest in airships, having flown its 55-meter-long AU-30 blimp at the recently reopened "dirigibledrome" in central Russia. The **AU-30** has a maximum payload of half a ton. It has flown 100 kilometers to the Russian air show known as MAKS, or International Aviation and Space Salon. The Atlant airship, an Augur project still in the design phase, would carry 16 tons of cargo.

At Aeros Corp., based in Montebello, California, the **Dragon Dream** demonstration vehicle completed its flight testing phase, and the company is moving ahead on development of two larger versions — the 66-ton-payload ML-866 and the 250-ton-payload ML-868. The prototype was damaged early this year when part of its hangar roof collapsed, causing a delay of about 10 months. But the project is back on track, says Aeros, and the company is planning to build 18 of the larger ships and four of the smaller ones.

Boling Associates, a Fresno, California, ad agency, plans to take advertising to the skies with a fully functional **hot-air craft**. The 135,000-cubic-foot airship carries four passengers and has 4,500 square feet of available advertising space. The craft, made in Germany by Gefa-Flug, takes only 45 minutes to inflate. It has a maximum speed of 23 mph and can fly up to five hours on a full tank of gas. After flying, it is deflated and folded up. This airship is much less expensive to operate than a traditional helium-filled type.

A little-publicized airship but one that is much appreciated is the **Navy MZ-3A**. The craft is propeller driven by two 160 horsepower Lycoming engines that enable it to travel at 50 knots with an operational payload capacity of 2,450 pounds. This manned, 178-foot. lighter-than-air blimp can remain aloft and nearly stationary for more than 12 hours performing various missions. It is government owned and contractor operated. The contractor, ISSI — Integrated System Solutions Inc. — employs highly qualified blimp pilots with special awareness training for the Washington, D.C., metropolitan area and experience operating within its airspace. The recent Washington-area mission was scheduled to conclude with the return flight to Naval Air Station Patuxent River, Maryland.

The MZ-3A airship is stationed at Naval Air Station Patuxent River, Maryland.

U.S. Navy

Reducing needless aviation parts replacement

by Lori Fischer

*The **Product Support Technical Committee** advances the quality, technology, and excellence of post-production aviation products and services by providing an international, industry-wide forum for networking and exchanging of best practices.*

Due to the aviation industry's increased emphasis on lean practices, new efforts were launched in 2014 to address the costs of instances of **no fault found**, in which parts are removed from aircraft due to suspected faults, but subsequent tests are unable to identify anything wrong with them.

Solutions to NFF problems can be quite challenging.

NFF sometimes results when product testing on the ground does not accurately replicate the temperatures, vibrations or other conditions of flight. In other cases, the problem may have to do with the electrical harness or other equipment attaching the part to the aircraft.

The Product Support Technical Committee launched three working groups in 2014 to address the NFF problem. These working groups aim to reduce NFF in their collective environments using a disciplined, lean methodology derived from lessons learned and the standards document **ARINC Report 672**, "Guidelines for the Reduction of No Fault Found." The guidelines offer a structured approach that is suitable as a baseline. Interested parties are adapting the 672 guidelines to fit their respective environments. It is from these activities that the ARINC 672 guidelines may be enhanced and the creation of NFF related standards such as fault reporting will ensue.

The first of the new working groups, an **engine/supplier group**, has finished a comparison of integrated performance requirements and test procedures. This review of applicable documentation is one of the first steps defined in the ARINC 672 guidelines. This working group has identified two different line replaceable units — parts designed to be easily plucked and replaced on an aircraft — which will be the focus of their follow-on efforts.

Meanwhile, an **airline/airframe/supplier group** is focusing on identifying high-volume NFF parts for the supplier, that is part of the working group, to review using an in-house NFF process blended with the committee's methodology. This working group has linked its NFF activity into the existing component reliability collaboration forums that get rolled up to the supplier/original-equipment-manufacturer executive levels to keep the focus on NFF reduction. The group's efforts were scheduled to be showcased at a component reliability collaboration symposium in December.

Just starting is a third working group whose airline/airframe members are familiarizing themselves with the disciplined/lean methodology that the committee is using as the template for the working group's efforts.

The removal/installation of an LRU.

US Air Force

A component bench test.

U.S. Air Force

Beyond these working groups, recent NFF reduction efforts recognize that NFF does not restrict itself only to avionics intermittencies on aging aircraft. It can affect line replaceable units in any category and at any age in the respective lifecycle.

Significant research and time is being invested on a number of NFF fronts via the collaborative efforts of universities, technical committees and industry.

The cross-disciplinary complexity of the issue and the historic lack of effort within industry to address the associated problem have hampered progress. The reluctance to share information (or proprietary restrictions) and the rush to market are also obstacles. Strict product support agreements or penalties regarding NFF thwart progress in this arena as well.

The AIAA Product Support Committee shares a common goal with the Through-life Engineering Services Centre at Cranfield University in the U.K. to educate and help guide the industry toward NFF reduction.

The stakes for these new efforts were made clear during the Air Transport & Operations Symposium and International Meeting for Aviation Product Support Processes at the Delft University of Technology in the Netherlands. It was reported that the NFF percentages for organizations not pursuing NFF reduction strategies were 40 percent for mechanical line replaceable units and 60 percent for avionic LRUs. Companies aggressively pursuing reduction strategies such as ARINC 672, CASH (Conserve All Serviceable Hardware) and HSM (Holistic Systems Maintenance) report having far less NFF percentages than those companies that do not.

Vertical lift reaches new heights

by Erasmo Piñero

*The **V/STOL Technical Committee** is working to advance research on the vertical take-off and landing aircraft.*

This year the **F-35B** expanded its role as the training platform for the next generation of V/STOL fighter pilots. Aircrew training is ongoing at Eglin Air Force Base, Florida, and Marine Corps Air Station Beaufort, South Carolina.

As of August, more than 65 percent of the F-35B flight test program was completed. The U.S. Marine Corps has been introducing the F-35B into its training pipeline and will eventually field 340 of the aircraft. These scheduled deliveries do not reflect planned orders from the United Kingdom (138) and Italy (69). In July, the United Kingdom launched the new-design aircraft carrier HMS Queen Elizabeth, which will operate Royal Navy F-35Bs.

The Bell Boeing **V-22 Osprey** team continues to pursue new capabilities for the tilt-rotor fleet, including air refueling demonstrations. Bell is also marketing the aircraft to foreign governments. As of April, the Bell Boeing team delivered more than 200 V-22s in both production versions. During the summer, V-22s conducted highly publicized humanitarian and search-and-rescue operations in the Far East and Africa.

The rotorcraft company AgustaWestland continues certification and production efforts for **AW609** civil tilt-rotor. In March and April more than 70 autorotations were conducted on one of the AW609 prototypes. Two of the aircraft are supporting the flight test program.

The U.S. Marine Corps vertical-lift fleet reached a major milestone with the May roll-out out of the Sikorsky **CH-53K King Stallion** heavy-lift helicopter. This new, powerful aircraft will replace the CH-53s and CH-53Es, both of which are nearing the end of their service life. A production-representative ground vehicle is being tested at Sikorsky's West Palm Beach, Florida, facilities, and a first flight is scheduled for late 2014.

In late July, the U.S. Army Aviation and Missile Research Development and Engineering Center down-selected two contestants for the **Joint Multi-Role Technology Demonstrator** program. Two teams, Sikorsky Boeing and Bell Helicopter, were selected to build flying technology demonstrators by 2017. Sikorsky Boeing is offering the **SB-1 Defiant**, a larger version of the X2, an experimental compound helicopter with coaxial rotors; and Bell is working on a clean-sheet tilt-rotor design, the **V-280 Valor**. Both designs will be capable of speeds greater than current Army rotorcraft. The long-term goal of the JMR program is to mature the technologies planned to be applied to a family of rotorcraft under the Future Vertical Lift program.

It is expected that the other two contenders, AVX and Karem Aircraft, will continue to receive funding for technology risk reduction.

Sikorsky

CH-53K King Stallion.

In March, DARPA completed its selection of four contenders for its **VTOL X-Plane**. Aurora Flight Sciences, Boeing, Sikorsky and Karem Aircraft were awarded Phase 1 preliminary design contracts for the development of a VTOL aircraft capable of speeds up to 400 knots and gross weights up to 12,000 pounds. Boeing has already flown a 17 percent-scale unmanned demonstrator. Phase 2 of the program will be awarded to one of the aforementioned competitors.

NASA's unmanned **GL-10 Greased Lightning** made a tethered flight test in August with free-flight tests planned for later in the year. The aircraft combines a vertical take-off and landing capability with the cruise efficiency of a long-endurance airplane. The aircraft's tilt-wing configuration is based on lessons learned from the previous concepts tested during the project and from VTOL research aircraft from the 1960s and 1970s.

New capabilities for the V-22 Osprey are being explored.

U.S. Air Force

Preserving the past

by Bill Barry

*The **History Technical Committee** works to preserve the record of aerospace advances and recognize their impacts on modern society.*

While many despair at the apparent loss of historical records covering the first century of flight and space history, a panel of **aerospace archivists** at AIAA's SciTech 2014 Forum went a long way toward dispelling the myths and providing guidance to those of us with materials that may be historically significant.

"Aerospace Archives: All is NOT Lost — Keepers of the Right Stuff," chaired by outgoing History Technical Committee Chairman Cam Martin, featured Debbie Douglas, curator of science and technology at the MIT Museum; Jane Odom, chief archivist at NASA; Dawne Dewey, head of special collections and archives at Wright State University; Marilyn Graskowiak, archivist at the National Air and Space Museum; and Elizabeth Borja, reference archivist at the National Air and Space Museum. The panelists gave particular attention to some of the highlights of the archival collections held by their organizations, both artifacts and documents. They also noted the wide variety of repositories around the United States that collect aerospace materials and their continued interest in acquiring items from individuals and organizations.

Asked what scientists and engineers should do with potentially valuable **documents and artifacts**, the panel had two unanimous messages. First, don't leave these items for your children to sort out. If you want to be sure your legacy does not wind up in a landfill, contact an archivist as soon as you start thinking about what you might donate. Second, don't weed out your papers yourself; let a trained archivist help you determine what is historically significant.

NASA

The first meeting of the National Advisory Committee for Aeronautics took place on April 23, 1915. NACA will celebrate its 100th anniversary in March.

The claim that **Gustave Whitehead** flew a powered, controlled aircraft more than two years before the Wright brothers was discredited this year by the Historical Group of the British Royal Aeronautical Society. In 2012, Jane's All the World's Aircraft astounded many by announcing support for the claim that Whitehead flew an airplane in Connecticut in 1901. In June 2013, Connecticut Gov. Dannel Malloy signed into law a bill establishing a state Powered Flight Day honoring Whitehead as the first to fly. This effort to rewrite history was roundly dismissed by U.S. historians, including Tom Crouch, vice chairman of the AIAA History Technical Committee and AIAA Fellow. This year, the Royal Aeronautical Society added its voice to the debate by issuing a formal statement in June. Their conclusion: "All available evidence fails to support the claim that Gustave Whitehead made sustained, powered, controlled flights pre-dating those of the Wright Brothers."

With the centennial of the creation of the National Advisory Committee for Aeronautics — **NACA** — coming on March 3, 2015, aerospace historians have been preparing events to mark the occasion. From 1915 until it became the institutional basis of NASA in 1958, NACA made fundamental contributions to the worldwide development of aeronautics, critical contributions to victory in World War II and security in the Cold War, and laid the basis for the Space Age. The first centennial event will be an invited panel discussion at SciTech 2015 on Jan. 6. "The NACA Centennial: An Assessment" will be chaired by Crouch and feature Roger Launius of the National Air and Space Museum, Jim Hansen of Auburn University, MIT's Douglas and Bill Barry from NASA. A number of other events, including a historical symposium at the National Air and Space Museum on March 3-4, are on the agenda for 2015.

The 2014 Gardner-Lasser Aerospace History Literature Award went to Bill Clancey for his path-breaking work on how the various teams made the Mars rovers a success in "Working on Mars: Voyages of Scientific Discovery with the Mars Exploration Rovers." The 2014 History Manuscript Award went to Lawrence R. Benson for his manuscript on supersonic boom research, "Quieting the Boom" (now a NASA publication).

Rockets, unmanned planes dominate legal scene

by Douglas Marshall

*The **Legal Aspects Technical Committee** fosters an understanding of legal areas unique to aerospace.*

The year brought out **aggressive litigation** and a bit of international mischief as launch industry giants elbowed and jostled each other for advantages. The long-dominant United Launch Alliance, a joint venture between Boeing and Lockheed Martin, is fending off legal attacks from SpaceX, industrial base challenges from Russia and the merger of two competitors in Orbital Sciences Corp. and Alliant Techsystems, known as ATK.

SpaceX filed a protest against the U.S. Air Force for its decision to award a sole-source block-buy contract for 36 launches to ULA. While SpaceX argued the deal is wasteful for taxpayers, the Air Force disagreed and defended its buy as a good deal for the taxpayer. The U.S. government asked a federal court to dismiss the lawsuit, arguing SpaceX lost its right to protest by not challenging the solicitation when it was issued in 2012.

For a short while, SpaceX secured a U.S. Court of Federal Claims preliminary injunction that blocked ULA and the Air Force from purchasing **RD-180 engines** used in ULA's Atlas 5 rocket. The relatively inexpensive but very capable RD-180 is produced by Russian company NPO Energomash. That company is caught up in contentions that it should be sanctioned in response to the growing crisis in Ukraine and Russia's illegal invasion and seizure of portions of that nation. It had been argued that payments for the engines effectively benefited Russian Deputy Prime Minister Dmitry Rogozin, who is subject to U.S. **economic sanctions** under Executive Order 13661. ULA contends the engine purchases should not be subject to sanctions. SpaceX was accused of trying to disrupt vital national security launches. The U.S. government formally filed a motion to dismiss the injunction, and that motion was granted.

In April, Orbital Sciences and ATK announced merger plans to create a new $5 billion company to be called **Orbital ATK**, whose offerings will include launch vehicles, satellites and defense systems.

While launch companies moved to enlist congressional and bureaucratic support for their respective interests, the legal dust-ups highlighted an important issue: whether the U.S. should stick with ULA, a proven entity that has achieved over 100 consecutive launches, or move in new directions in an attempt to achieve cost savings in an era of declining budgets. Stirring the pot, Rogozin threatened to no longer allow RD-180s to be used for launches of U.S. military spacecraft, though he has yet to follow up on the threats. In the meantime, the Air Force took programmatic steps to reduce acquisition risks associated with any lost access to the RD-180s.

The Air Force verified that SpaceX's Falcon 9 v1.1 rocket completed three flights. The completion of three flights is one part of the process for SpaceX to achieve certification and be eligible to be awarded contracts as part of the Evolved Expendable Launch Vehicle program.

The Space Data Association signed an agreement to participate in the U.S. Defense Department's **Space Situational Awareness Sharing Program**. The SDA press release says that it is the DoD's first such agreement with a non-satellite operator. The U.S. Strategic Command administers the SSA Sharing Program, which is intended to increase the safety, security and sustainability of the space domain.

The satellite industry celebrated moves to finalize regulations that remove some satellite hardware and technologies from the **U.S. Munitions List**, a registry of militarily sensitive technologies whose exports are tightly controlled by the State Department. The new rules, which go into effect 180 days after its May 7 draft was published, move items from the USML to the **Commerce Control List** and ease their export to 36 countries. Exports of space-related hardware, technologies, and services to China and certain other countries remain strictly controlled, however.

SpaceX

SpaceX's Falcon 9 v1.1.

Unmanned aircraft systems continue to generate a smorgasbord of legislative and litigation responses to explosive growth in the use of small, affordable flying cameras. Companies such as **Amazon, Google**, news and entertainment conglomerates, and others have announced plans to employ unmanned aircraft for a variety of commercial purposes. They are putting pressure on the FAA to expedite rules that allow continued growth of what is estimated to be an $82 billion industry, creating 100,000 jobs. Six test sites mandated by Congress went operational this year, and the first commercial operations were approved for Alaska's North Slope. Two pending enforcement cases received media coverage after an administrative law judge ruled in one of them that the FAA did not have regulatory authority over small commercial drone operations. Regulations for small unmanned aircraft are due for release via a notice of proposed rule-making in December. Three states passed anti-drone bills, three were defeated and 12 more states have introduced similar legislation, the major concerns being privacy and fears of covert surveillance by law enforcement agencies.

Managing amid growing challenges

by Tom Goudreau

*The **Management Technical Committee** promotes sound management practices and helps aerospace managers understand the issues that impact their success.*

The aerospace and defense industries have been affected by a year of conflict from Ukriane to the Middle East and Africa.

Russia's actions in Eastern Europe and the **shootdown** of a Malaysia Airlines plane over Ukraine have put pressure on established space and aerospace collaboration. Caught between Western economic sanctions and Russian actions in Ukraine is the supply of Russian-built **RD-180 engines** used on Atlas 5 launch vehicles to loft satellites critical to U.S. national security. Even nondefense multinational efforts such as plans for the International Space Station have become less certain as a result of the increased global tensions.

Neither expanding global conflicts nor the decision to strike ISIS in Iraq and Syria seems to have affected the certainty of U.S. defense **budget cuts**. With Budget Control Act spending caps in place, the debate appears to have shifted from "how much should be spent on defense" to "what should be bought with the limited defense dollars we have." While some major procurement programs could be simply "pushed to the right," deferring new Defense Department equipment deliveries will not be enough. Hard choices such as whether equipment like the A-10 close air support aircraft are retired and how many military and civilian positions will be eliminated continue to be debated.

The Russian-built RD-180 engine is used to power the Atlas 5 launch vehicle.

United Launch Alliance

The decline in defense spending is challenging the industry to find new sources of revenue. These potentially include next-generation intelligence, surveillance, reconnaissance and precision strike technologies, cybersecurity, new commercial ventures, and also acquisitions of synergistic businesses.

Meanwhile the **commercial aerospace** sector is setting records for production of aircraft due to the accelerated replacement cycle of obsolete aircraft. Passenger travel demand continues to grow, especially in the Middle East and the Asia Pacific regions. Fuel costs for commercial airliners are driving research into next-generation fuel-efficient aircraft.

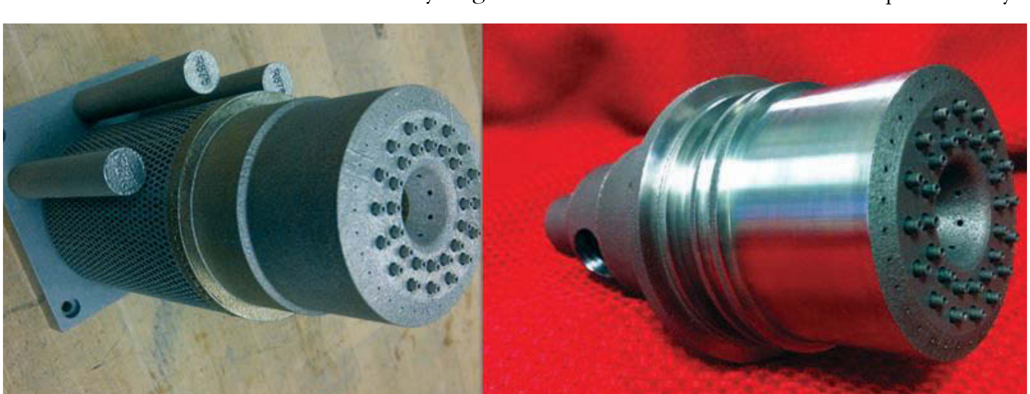
Aerospace companies are implementing a range of affordability initiatives for both defense and commercial customers. Aerospace companies have used **3-D printing**/additive manufacturing since the 1990s, beginning as stereo lithography. Parts made this way have been enabling rapid prototyping, compressing the design cycle. Current research is focused on applying the process to difficult-to-produce, high-performance components consistently and repeatedly.

Today's 3-D printing machines are more capable and affordable than they were 20 years ago. Some 3-D printers can now produce metal alloy parts made of titanium and nickel. Aircraft engine part manufacturers, for example, are working to leverage 3-D printing to replace traditional cast and forged parts production processes where it makes sense. Cost, time and material properties will determine what parts are forged, cast or produced with 3-D printing tools.

Standing between the industries willingness to be innovative and agile and U.S. government customers' desire to control costs and avoid delays is the **acquisition system**. An improved acquisition process has not emerged, but not for a lack of trying. Despite the 2009 Weapons Systems Acquisition Reform Act and the Pentagon's two-plus versions of Better Buying Power policy mandates, progress has been slow. Congress is expected to take up the issue again in early 2015.

Compounding the acquisition reform challenge discussed at AIAA's 2014 Aerospace Today & Tomorrow conference is that the problem is one of both process and culture. Changing government and industry cultures takes time. Getting incentives right is one opportunity; confronting and challenging risk aversion is another.

The **House Armed Services Committee** study underway could result in provisions being passed as part of an upcoming authorization bill. The stakes for the aerospace industry are significant.



NASA Marshall Space Flight Center

A 3-D printed rocket injector (left) as it looked immediately after it was removed from the laser melting printer. On the right, the injector part after inspection and polishing.

Continued growth for satcom

by Thomas C. Butash

*The **Communications Systems Technical Committee** is working to advance communications systems research and applications.*

The commercial communications satellite industry was on track for continued growth this year, with companies focused on innovative systems with greater effective capacity and lower on-orbit costs. Investments increased in flexible payloads capable of allocating bandwidth and power across multiple beams in response to dynamic service demands. There is also growing interest in **all-electric** and **hybrid propulsion** systems that will lower launch costs.

Through August, 18 geosynchronous communications satellite contracts were awarded: six to Space Systems/Loral, five to Thales Alenia Space, three (including two with all-electric propulsion) to Airbus Defence & Space, two to Dauria Aerospace and one each to Orbital Sciences and Boeing. This pace suggests 27 satellite awards by year's end, indicating continued expansion over the 25 awards in 2013 and 16 in 2012. A mid-year Satellite Industry Association report confirmed industry expansion outpacing global economic growth.

Interest in high-throughput satellites to provide **broadband** service increased, with Euroconsult predicting growth through 2014 and beyond. Several HTS contracts were awarded — Intelsat 35e, SES-12, Eutelsat 172B and HYLAS 4 — while other satellite broadband access systems also expanded.

SSL

Space Systems/Loral was selected in June to build Hispasat 1F, a multimission communications satellite for the Hispasat Group.

O3b became a global broadband access service provider with the July launch of its second flight of four satellites. The most intriguing entrant into the market came with Google's backing of WorldVu Satellites, which acquired Ku-band spectrum originally allocated to SkyBridge, to launch a Teledesic-like low-Earth-orbit constellation of 360 satellites for global Internet service.

The year opened with Lockheed Martin Space Systems' announcement of plans to re-enter the commercial satellite communications market, followed by Orbital Sciences' and ATK's second quarter announcement of their planned merger as Orbital ATK.

Industry expansion continued with Indonesian bank BRI's selection of SSL to build BRIsat to provide dedicated satellite communications for its 9,800 branches, 100,000 electronic channel outlets and 50 million customers. BRI thus becomes the first bank to procure a dedicated satellite for its network operations.

SpaceX continued to be a disruptive force in **launch services.** With 11 Falcon 9 launches through August and the most affordable ride for five metric tons to geosynchronous transfer orbit, SpaceX reinvigorated competition. Eutelsat and SES pressured the European launch industry to match SpaceX's prices. SpaceX challenged United Launch Alliance's long-running duopoly on U.S. government satellite launches and received certification to compete in the Evolved Expendable Launch Vehicle program. ULA, International Launch Services and ISS Reshetnev are considering dual-launch services to remain competitive, while Arianespace is tuning its dual-launch model. Interest in all-electric or hybrid propulsion satellites, facilitating either Falcon 9 or dual launches, heightened with the Eutelsat 172B, SES-10 and SES-12 awards and investments by Airbus Defence & Space, SES and Thales Alenia Space in all-electric systems.

Flexible satellites, capable of allocating bandwidth and power in response to changing demands, although not entirely new, saw a renaissance in capturing almost 30 percent of the awards through August. Intelsat 35e EpicNG and SES-12, in particular, will employ digital onboard processing to maximize bandwidth distribution flexibility.

Alphasat's Aldo Paraboni Q/V band payload experiment will pave the way for increased HTS capacity. And Inmarsat, in response to the disappearance of the Malaysia Airlines plane, offered free communications for worldwide aircraft tracking over its global satellite network, thus facilitating a "black-box in the cloud" system for preventing future tragedies like the loss of flight MH370.

The U.S. Air Force Space and Missile Systems Center and its contractors completed Protected Tactical Service Design for Affordability studies, paving the way for 2015 flight demonstrations and next-generation military satellite communications architecture definition. SMC's Hosted Payload Solutions awards facilitate simplified contracting for such cost-saving arrangements.

Long-awaited U.S. export control reform became a reality as most satellites were removed from the State Department's U.S. Munitions List and transferred to the Commerce Control List.

Computing for reliability, affordability

by Rick Kwan

*The **Computer Systems Technical Committee** works on advancing the application of computing to aerospace programs.*

Computing in aerospace operates over a spectrum of friendly and extreme environments, where "friendly" is a matter of human perception. Reliability in extreme environments and affordability often seem to be mortal enemies clashing on a battleground of engineering designs. But that may be changing as new technologies and strategies gain ground.

An autonomous unmanned aircraft or spacecraft — or a smartphone — contains an embedded system with a **system-on-a-chip**, or SoC, which is in turn composed of multiple cores, often of identical computer central processing units, or CPUs. But sometimes a core may be a general-purpose graphics processing unit, known as a GPGPU, that facilitates fast 3-D calculations. Or it may be a DSP to facilitate digital signal processing. Or it may be a serial I/O protocol processor to handle a data stream or to support encryption.

The variety of cores that can fit into an SoC has led to a cascade of terrestrial applications: smartphones, smartwatches, the Internet of Things. As in aerospace, these often mobile devices are sensitive to size, weight and power issues, and perhaps insensitive to shock, lack of convection, etc. For low-Earth orbit, the gap between terrestrial and spaceborne devices is closing. For deep space, a new generation of processors is arising.

One strategy for reducing cost is redundant use of commercial off-the-self parts. Sometimes this means many of the same part in a vehicle; sometimes it means many vehicles.

Start-up company **Planet Labs** has developed the Dove spacecraft, a 3U CubeSat (30x10x10 centimeters) built from non-space, commercial off-the-shelf COTS components. Flock 1, comprised of 28 Doves, was launched to the International Space Station in January and deployed into orbit weeks later. In fact, the San Francisco company has launched 71 Doves since its founding in a garage in April 2012. The use of COTS parts has allowed the company to design and fly many iterations of the spacecraft design, with each iteration lasting a few months. A similar strategy has been employed with the PhoneSat nanosatellites developed at NASA's Ames Research Center; and with TechEdSat, jointly developed by NASA Ames and San Jose State University.

The cockpit of the Dragon v2 has movable touch-panel displays.

SpaceX

Multicore SoCs are making their way into **deep space missions** as well. In the last several years, NASA and the Defense Department have found that marked improvements in technology can be brought into radiation-hardened processor design. The Air Force Next Generation Space Processor Program aims for advanced multicore rad-hard processors for use in the 2020-2030 time frame.

Planet Labs

A flock of Dove satellites was launched to the International Space Station in January and deployed weeks later.

Meanwhile, a new generation of multicore space processors is now becoming available. BAE Systems is developing a new generation of radiation-hard Power/PowerPC processors. Derived from the Freescale QorIQ Power Architecture, the **RAD5545** is a multicore SoC using 45 nanometer silicon-on-insulator technology of the IBM Trusted Foundry. It is the first member of the RAD5500 series, which follows in the footsteps of the RAD6000 and RAD750 processors that are prevalent on deep space missions. The RAD5545 is expected to provide a tenfold performance increase over the RAD750. By nature, DSP is a multicore problem on multiple levels. The BAE Systems RadSpeed DSP employs two cores of 76 processing elements each, thus doing over 150 computations in parallel.

Computing technology is becoming keenly apparent in the new generation of human commercial spaceflight vehicles being readied for flight tests. Both the SpaceX Dragon v2 and Boeing CST-100 crew vehicles employ large movable flat-screen touch-panel displays, which replace a large number of discrete cockpit instruments of earlier crewed spacecraft. While "glass cockpits" and "fly-by-wire" are no strangers to the aviation realm, computing in upcoming crewed space vehicles marries highly reliable embedded control-critical computing with more complex, often error-prone, human interaction interfaces.

Creating unmanned data links

by Denise Ponchak and John R. Moore

The ***Digital Avionics Technical Committee*** *advances the development and application of communications, navigation and surveillance systems used by military and commercial aircraft.*

NASA

Using a NASA S-3 Viking, experts from Rockwell Collins and NASA tested a communication system that will enable unmanned craft to safely operate in the national airspace.

The prototype command and non-payload communication system in its test rack in the rear section of an S-3 Viking.

NASA

In the FAA Modernization and Reform Act of 2012, Congress tasked the FAA with enabling routine access for civil unmanned aircraft to the National Airspace System by 2015. One of the key technology gaps in realizing this vision is the lack of certification standards and equipment for a command-and-control data link.

The World Radio Conference 2012 provided two allocations of protected aviation-safety spectrum for terrestrial transmitters for this purpose, one in L band and one in C band. In July 2013, the RTCA, founded in 1935 as the Radio Technical Commission for Aeronautics and now an advisory committee to the FAA, established Special Committee 228 — **Minimum Operating Performance Standards for Unmanned Aircraft Systems** — to create key standards leading to avionics Technical Standards Orders for key enabling technologies, including a **command and non-payload communication**, or CNPC, data link.

NASA Glenn Research Center and Rockwell Collins have come together in a jointly funded cooperative agreement to develop and test a prototype system in the newly allocated spectrum to support validation and verification of the RTCA performance standards. This effort is a five-year program, with five deliverable **prototype spirals** that provide incremental development and testing of a new, certifiable waveform for civil unmanned aircraft. The third spiral development was delivered to NASA in July for testing later in the year.

In developing this prototype CNPC system, **NASA** and **Rockwell Collins** did a broad assessment of existing communication waveforms to see if any current solutions could be adapted for use. For the upper layers of the communication protocol stack, it was determined that IEEE 802.16 (WiMax) could provide an appropriate basis. For the lower layers (specifically including the physical layer for over-the-air transmission) it was determined that a new waveform was needed.

Rockwell Collins took seed requirements from earlier RTCA Special Committees and conducted a trade study on technology candidates against a set of objective evaluation criteria. The trade study recommended a communication architecture that became the basis for the prototype system. This included support for point-to-point communications (as with most unmanned aircraft today) and also with a capability for orderly integration of local, regional or, perhaps someday, even a national network infrastructure.

Key attributes of the system include: availability, integrity and continuity of function appropriate for the intended safety of life application; capacity/scalability to support the large number of unmanned aircraft that are anticipated to develop in the next several decades; and reduced complexity to lower acquisition and life cycle costs.

Because many unmanned aircraft are smaller than their manned counterparts, there are several unique challenges to be addressed including: size, weight and power consistent with smaller airframes; cost proportional to the overall aircraft system; and certification risk controlled by looking to determinism and predictability in operation wherever possible.

NASA and Rockwell Collins began flight testing the prototype system in spring of 2013, incrementally adding and validating new capabilities. The three spirals delivered to this point demonstrate: 1) basic L band operation, one aircraft, one ground tower; 2) basic C band operation with improved Doppler performance, tower-to-tower handoffs, internal channel estimation metrics for multipath; and 3) automatic unmanned aircraft discovery and network ingress, multiple aircraft and multiple tower simultaneous operation, master/slave operation in ground towers.

Testing to date has involved manned aircraft carrying CNPC radios as payloads. In June, a **NASA S-3 Viking** and a **University of Iowa Operator Performance Laboratory Beechcraft Bonanza** were used as surrogates for unmanned aircraft during tests at Eastern Iowa Airport in Cedar Rapids, Iowa. The aircraft tested the ability of unmanned aircraft to hand off communications from one tower to another and the ability of a single tower to communicate to multiple aircraft.

Future testing phases will integrate a ground control station with CNPC radios to fly unmanned aircraft through their automatic flight controls. This will come first in optionally piloted surrogate aircraft, and eventually on an unmanned aircraft as the primary command-and-control link.

Applying computation for security, efficiency

by Kristen Rozier

*The **Intelligent Systems Technical Committee** works to advance the application of computational problem solving technologies and methods to aerospace systems.*

Robonaut 2 completed its fixed-base activities onboard the International Space Station and received its climbing legs in August 2014. R2's torso finished stanchion activities by manipulating space blanket materials, demonstrating increasingly difficult hand movements, and performing tasks under teleoperation control by astronauts wearing motion capture equipment and virtual-reality visors. Advanced tactics included grabbing a tumbling roll of tape in microgravity and manipulation of tethers, connection hoses and clamps.

In the domain of cyberphysical systems, aircraft including the unmanned variety utilize off-vehicle network connections for command and control, sharing sensor data and coordinating missions. Such connectivity can expose software vulnerabilities exploitable by cyberattackers. Experts working under **DARPA**'s High-Assurance Cyber Military Systems program, or **HACMS**, including Rockwell Collins, Boeing, the National Information Communications Technology Australia Center, Galois and the University of Minnesota, are building software to be provably secure against many classes of cyber attacks based on a high-assurance autopilot software stack with system architecture models for formal analysis. According to DARPA Program Manager Kathleen Fisher in January, DARPA's **Red Team** was unable to hack the team's research quadcopter given six weeks and full access. Research is transitioning to Boeing's **Unmanned Little Bird** helicopter.

To encourage earlier and broader adoption of formal methods within system development, the Centre of Informatics at Brazil's Universidade Federal de Pernambuco in Recife released **NAT2TEST**, an application that automatically generates test cases from **natural language** requirements. NAT2TEST analyzes the requirements' syntax based on a controlled, fixed grammar natural language; uses thematic roles to form the initial interpretation; and derives an abstract formal model from which alternative formal notations and test cases are generated. NAT2TEST was compared against random and specialist-written test cases and outperformed both of them when demonstrated on an **Embraer** aircraft's priority command controller and a **Mercedes** automotive turn indicator system.

To improve unmanned combat aerial vehicle operations, the University of Cincinnati's Morphing and Optimization Systems Technology for Aerospace Laboratory and the Air Force Research Lab Control Science Center of Excellence created the Learning Enhanced Tactical Handling Algorithm. **LETHA** utilizes multiple intelligently designed fuzzy systems to hierarchically break down the control of the aircraft and allow for the learning capabilities of genetic fuzzy systems to be applied to problems with larger complexity and scale. Set for release by **Psibernetix Inc.**, LETHA increases the efficiency, scalability and transparency of uninhabited operations by integrating self-defense missiles, laser weapon systems, mission planning, communications and responses to off-nominal conditions.

In the field of big data and domain-specific machine learning techniques applied to aircraft turbulence, researchers are re-envisioning models of **turbulent fluid flow** with previously unavailable accuracy. Funded through NASA's **LEARN** research support project for educators, researchers from the University of Michigan, Stanford University, Iowa State and Pivotal Inc. are utilizing large-scale data-driven simulation techniques to enable the construction of more accurate turbulence models infused with knowledge directly derived from large amounts of data from higher-fidelity simulations and experiments. This team is rethinking the way that turbulence models are created and embedded into flow solvers by generating an online database of curated test cases open to the modeling community.

Robonaut 2,with its freshly installed climbing legs, will be able to assist astronauts on the space station.

NASA

Working within the domain of flight safety, piloted simulations by **NASA Glenn** researchers demonstrated a new software algorithm called the **Model-Predictive Automatic Recovery System**. This software protects aircraft on the verge of a loss-of-control accident, especially during an unstabilized approach. The on-board model continuously predicts if the aircraft is able to perform a go-around from its current flight condition without dropping below a specified altitude, taking over control only when it determines that any delay to initiate a go-around could result in an accident. The system prevents dangerous situations, such as approaching too low and too slow, like the Asiana flight 214 into San Francisco in July 2013.

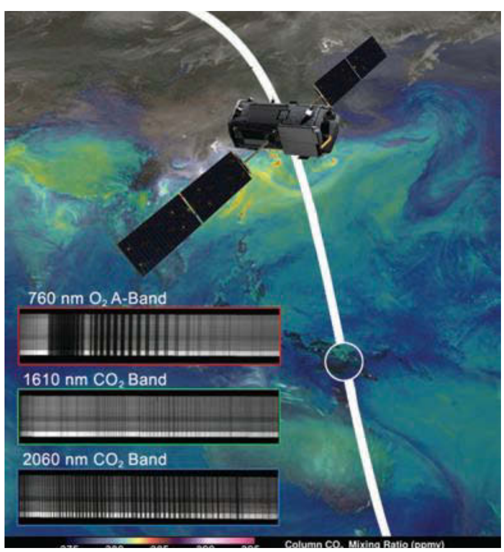
Smaller, smarter sensor, fusion systems

by Timothy L. Howard, Domenico Accardo and Wei-Jen Su

The ***Sensor Systems and Information Fusion Technical Committee*** *advances technology for sensing phenomena and combining the resulting data for display to users.*

Swiss company SenseFly has introduced **eBee**, a portable, lightweight drone that collects imagery with a 16-megapixel camera for aerial mapping. With a wingspan of less than 1 meter and takeoff weight under 1 kilogram, it can cover up to 12 square kilometers in a single flight, with post-processing software that generates maps down to 3-centimeter precision at the ground.

A derivative product introduced in April, the eBee Ag, is intended for **precision agriculture** and offers four choices of imaging sensors: standard red-green-blue, near-infrared, red-edge and multispectral. The electrically powered eBee's airframe is made with flexible foam. The vehicle is hand launched and can perform a safe linear landing on its belly. The system is the outcome of research



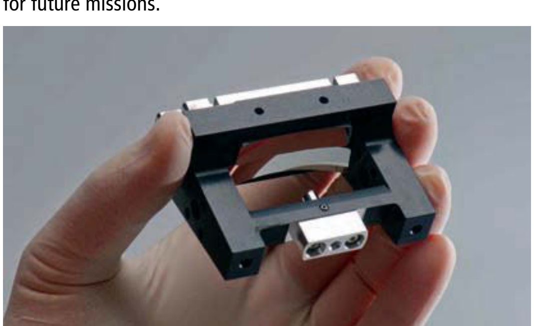
NASA/JPL-Caltech/NASA Goddard

OCO-2 records bar code-like spectra of molecular oxygen and carbon dioxide in Earth's atmosphere.

by Professor Jean-Cristophe Zeuffrey from École Polytechnique Fédérale de Lausanne, whose studies have focused on developing bio-inspired technologies to be used for robotic applications, such as a collision-avoidance approach based on optical flow that is derived from behavioral studies on bees.

The European Space Agency is developing a **miniature hyperspectral sensor** suitable for use in CubeSats. The system is based on a three-mirror anastigmat, a popular all-reflective optical design that until now has only been used in much larger instruments. The new version was adapted from a larger predecessor by using improved diamond-point turning technology to manufacture the mirrors. It will provide a 50-degree field of view in up to hundreds of narrow spectral bands while fitting within the standard 10-centimeter CubeSat format. A prototype optical telescope has been built by Dutch company VDL ETG under contract to ESA and will be coupled with off-the-shelf electronics and advanced data-compression software.

This CubeSat three-mirror telescope will feed a hyperspectral sensor for future missions.



ESA

Israel Aerospace Industries has introduced an integrated **sensor intelligence** system that allows unmanned aircraft to build up a detailed picture of their surroundings. It identifies and tracks the sources of signals from multiple types of emitters and combines them into a database known as an "electronic order-of-battle picture." Previously this capability was only available using much larger platforms because of the large antennas required. The new system will fit on unmanned aircraft such as IAI's Heron 1, which is used by a number of air forces worldwide. It can also be hosted on ship-based or ground unmanned platforms.

Researchers at MIT and Hebrew University of Jerusalem developed a processing technique to produce high-resolution **terahertz images** by exploiting signals from imaging sensors that have many fewer elements in the array than those needed using traditional processing techniques. This provides a significant reduction in the required antenna size while maintaining performance and will allow new systems such as "personal radar" to be feasible at low cost. It will also enable the use of millimeter-wave imaging applications for compact platforms such as mini and micro unmanned vehicles. This result can be exploited in several applications, such as surveillance, visual navigation and sense-and-avoid systems.

NASA's **Orbiting Carbon Observatory-2** achieved its final orbit and began returning science data in August. The spacecraft has a three-spectrometer optical instrument that will provide the most detailed look yet at sources and sinks of carbon dioxide on Earth. The spectrometers operate in the near-infrared region of the spectrum and are fed by a common telescope. Each one produces 9,000 frames of data per orbit, with each frame containing data from eight spectral bands. The footprint of each measurement is about 1 square mile on the ground. In addition to carbon dioxide the instrument will also measure molecular oxygen, which will aid in correcting for the effects of clouds, aerosols and surface topography.

Open source, cybersecurity top software issues

by Misty Davies and Sam Adhikari

*The **Software Technical Committee** focuses on software engineering issues for complex and critical systems, including requirements, design, code, test, evaluation, operation and maintenance.*

Software delays could set back the F-35 program by more than a year, according to the GAO.

Lockheed Martin

Open source systems and cybersecurity issues dominated aerospace software developments in 2014.

The Government Accountability Office issued a report in 2013 on the relative use of open source systems for unmanned aircraft. Open source systems include **modular design**, allowing software components to be more easily replaced. The GAO reported that the U.S. Navy led the other services in the use of open source systems; Army and Air Force unmanned systems had cost overruns and upgrade difficulties attributed to their slower adoption of open source systems. In particular, the GAO noted that arguments against the early development of open source systems turned out to be inaccurate. In particular, no cost savings were found by purchasing commercial off-the-shelf software or using initial prototypes of software systems for the Army and Air Force unmanned systems that the GAO examined. In response to the report, which included recommendations for improving implementation of open source systems in DoD, the House mandated that GAO provide a briefing on private industry best practices for developing an open source approach. In the briefing, released in June, the GAO said its open source recommendations were supported by data from the oil and gas industry, a satellite voice and data company, and a private unmanned aircraft software manufacturer. The GAO's conclusion in this year's report was that DoD still had not implemented the 2013 recommendations.

Boeing and the FAA began working together to prevent **cyberattacks** on the Boeing 777. In November 2013, the FAA issued special conditions designed to ensure that the in-flight entertainment system could not be used to compromise aircraft control systems. Earlier FAA regulations and guidance had not anticipated interconnected system network architectures. In June, the FAA ordered Boeing to make similar changes to the Boeing 737 model. Changes are also being made to the 747 and 787 models.

The AIAA Aerospace Cybersecurity Working Group, led by the Software Technical Committee, arranged the "Cybersecurity in Space Systems Panel Session at SciTech 2014.

Both setbacks and successes in aerospace systems were attributed primarily to software. In March testimony on the F-35 Joint Strike Fighter, the GAO told the House of Representatives that software **development and testing delays** would cause additional program delays — up to 13 months — and cost overruns . Also in March, the general in charge of the F-35 program predicted delays of four to six months.

In May, a software glitch in the **En Route Automation Modernization** air traffic control software led to over 200 canceled or diverted flights. The ERAM software was attempting to keep a U-2 spy plane from colliding with commercial aircraft, even though the U-2 was at 60,000 feet — nearly four miles above most passenger jet traffic.

On a positive note, NASA's Lunar Atmosphere and Dust Environment Explorer mission was completed in April with its planned lunar impact. **LADEE** was built using a modular common bus architecture for both the hardware and software, and leveraged the reuse of the open source Core Flight Executive and Core Flight Software systems developed by NASA's Goddard Space Flight Center.

The LADEE program has been noted for its drastically lowered development costs; the mission was accomplished on time and on budget.

NASA Wallops

The Minotaur V rocket with LADEE aboard launches.

Progress made on cleaner, more efficient flight

by Keiichi Okai and Gary Dale

*The **Green Engineering Program Committee** promotes a holistic, systems approach to improved energy efficiency, sustainability, renewable energy and design.*

Significant advances in electric aircraft technology were achieved this year. Airbus flew its **E-Fan** electric demonstrator and announced the formation of a new Airbus Group subsidiary, VoltAir, to build two- and four-passenger versions and to study a regional-sized airliner.

JAXA, the Japan Aerospace Exploration Agency, is performing manned flight demonstration tests using a Diamond HK36TTC-ECO motor glider with a 60-kilowatt, JAXA-developed electric-powered propulsion system through its Flight demonstration of Electric Aircraft Technology for Harmonized Ecological Revolution, or **FEATHER**, project.

The CAFE Foundation personal aircraft organization held its annual conference with a large audience of electric aircraft enthusiasts, especially for small electric vehicles.

The Boeing Phantom Eye unmanned hydrogen-fueled plane.

Boeing

The **Large Electric Aircraft Propulsion Technology** workshop attracted nearly 50 participants from the Defense Department, NASA, industry and academia to discuss views on electric-based propulsion for future large aircraft, identify common technical challenges, and examine near-term plans and collaborative opportunities.

The NASA-sponsored Boeing Subsonic Ultra Green Aircraft Research team completed an update of its **SUGAR Volt hybrid electric airliner** concept and identified technology options for the 2030 to 2050 timeframe.

Biofuels and their adoption for aviation continued to make important strides around the world, including certification of alternative production pathways for biofuels. In Japan, progress was made establishing a supply chain for next-generation aviation fuels by 2020. The University of Tokyo, Boeing, Japan Airlines, Nippon Cargo Airlines, Narita International Airport and Japan Petroleum Exploration formed a group called the Initiatives for Next Generation Aviation Fuels. Brazil's GOL Airlines, with Boeing, launched commercial flights using a newly approved sustainable aviation biofuel made from **sugar cane**. Collaborating with Amyris, they conducted flights from Orlando, Florida, to São Paulo.

Other fuel alternatives are also being developed. The Boeing **Phantom Eye**, a cryogenic hydrogen-fueled unmanned plane, flew tests at Edwards Air Force Base, reaching altitudes greater than 43,000 feet and flying for more than five hours. A future version is planned to stay aloft up to 10 days.

The Air Force Research Lab completed initial studies with Boeing and Lockheed Martin on **liquified natural gas** as an alternative fuel. Lockheed studied a dual-fuel C-130 with LNG in two external fuel tanks. Boeing studied a dual-fuel KC-10 with LNG tanks in the cargo bay. The studies showed large cost savings with the current fleet and huge cost savings if future mobility systems are included.

NASA, the German Aerospace Center DLR, and the National Research Council of Canada began a flight test campaign in May to study **emissions** and **contrail formation** from new blends of aviation fuels that include biofuel from renewable sources. The campaign, called ACCESS 2 for Alternative Fuel Effects on Contrails and Cruise Emissions II, builds on a first series of ACCESS flights in 2013. Flying as high as 40,000 feet, the four CFM56 engines on NASA's DC-8 burned fuel blends — either traditional Jet A or a 50-50 blend of Jet A and renewable alternative fuel of hydro processed esters and fatty acids produced from camelina plant oil — while DLR's Falcon 20-E5, NRC's CT-133 and NASA's HU-25C measured emissions and observed contrail formation. Preliminary results confirmed that the biofuel blends tested substantially reduce emissions of black carbon, sulfates and organics, and new data was gathered to aid in developing theories about contrail formation.

The U.S. Air Force's Surfing Aircraft Vortices for Energy project, known as **$AVE**, was elevated to an Advanced Technology Demonstration initiative this year after encouraging test results in 2013. Two C-17s flew in formation between California and Hawaii and demonstrated a 10 percent fuel burn reduction by the trailing aircraft. The $AVE ATD will address software improvements, pilot training and extension of the technology to other aircraft. AFRL also funded a study with Lockheed Martin to examine formation flight for C-130s and C-5s. Simulations showed fuel savings ranging from 5 to 14 percent and identified communications and sensor modifications needed for automatic formation flight.

A NASA-funded Boeing team tested a half-span model of a fuel-saving truss-braced wing airliner configuration in a wind tunnel at the Langley Research Center, demonstrating high efficiency with a high span flexible wing.

The Boeing 787 **ecoDemonstrator** airplane took to the skies for flight testing, carrying 30 technologies aimed at improving operational efficiency, reducing fuel use and quieter operation. Onboard monitoring equipment took samples of the atmosphere and analyzed for carbon dioxide content and other greenhouse gases.

Flying faster with collaboration

by Kevin Kremeyer

*The **Hypersonic Technologies and Aerospace Planes Program Committee** works to expand the hypersonics knowledge base and promote continued hypersonic technology progress through ground and flight testing.*

To achieve more within constrained budgets, countries, organizations and companies interested in hypersonic capabilities are starting to coordinate their global research efforts. The past year was marked by large programs being announced, concluded and executed, as well as more focused efforts, concentrating on specific aspects of hypersonic flight.

Boeing wrapped up its unmanned X-51 program after its demonstration of powered Mach 5+ flight in May 2013. Lockheed Martin will continue work on its **Hypersonic Test Vehicle-2** remediation program through 2015 under the Defense Advanced Research Projects Agency.

In January, China demonstrated its hypersonic glide vehicle at **Mach 10** after scaled ground tests in its hypersonic shock tunnel, which is larger than any other of its kind in the world. Also, China's Chengdu Aircraft Corp. is leading the development of a hypersonic scramjet engine test platform similar to NASA's X-43A.

Other future demonstration programs include:

• The **Advanced Hypersonic Weapon** tests by the U.S. Defense and Energy departments under the Conventional Prompt Global Strike program. The most recent test was aborted shortly after launch on Aug. 25.

• **HIFiRE 6**, a partnership among the U.S. Air Force Research Laboratory, Boeing, GoHypersonic, the Australian Defence Science and Technology Organisation and White Sands Missile Range. The program will evaluate the functionality and performance of an adaptive control law for unstable, unpowered Mach 6+ flight with tests through 2016.

• Continued testing of the Indian **BrahMos** platform and Russian **RS-26** and **S-500** programs.

In addition to defense-oriented programs, DARPA has begun the first phase of its Experimental Spaceplane program, known as **XS-1**, and awarded prime contracts for Phase 1 to Boeing (working with Blue Origin), Masten Space Systems (working with XCOR Aerospace) and Northrop Grumman (working with Virgin Galactic). The XS-1 program aims to develop a fully reusable unmanned vehicle to provide aircraft-like access to space and deploy small satellites to orbit using expendable upper stages. Along these same lines, the British government and the European Space Agency awarded Reaction Engines $100 million to develop a heat exchanger for **SABRE** — the Synergetic Air-Breathing Rocket Engine — which would power the planned Skylon, an 83-meter-long unmanned space plane. Japan also renewed its commitment to achieving hypersonic transpacific flight by 2025 by initially focusing on ground tests to support reusable rocket and air-breathing launch vehicles.

These programs require more thorough understanding and control of finer points surrounding flow control, boundary layers, kinetics and thermal considerations, and these are being ardently pursued by organizations around the world, including NASA, ESA, the Japan Aerospace Exploration Agency (JAXA), the German Aerospace Center (DLR), and the Chinese and Russian Academies of Sciences, to name a few. In addition to the world-class facilities being set up in China, AFRL and the Arnold Engineering Development Complex announced a partnership to establish a new High Speed Experimentation Branch at Arnold Air Force Base, Tennessee.


XS-1 Experimental Spaceplane

Northrop Grumman


Falcon HTV-2

Lockheed Martin

Much of the necessary fundamental research is being executed at universities around the world, including:

• The University of Queensland, Australia, is actively investigating speeds up to Mach 8.

• Japanese universities are in strong collaborations with JAXA and industry to develop highly instrumented hypersonic test articles.

• DLR, EADS and Universität Stuttgart in Germany continue their ATLLAS II, LAPCAT-II and HEXAFLY programs.

• In June, CUBRC highlighted the need for more exact turbulence models through blind validation studies to model shock wave interactions with developed hypersonic boundary layers.

• PM&AM Research is dramatically expanding flight envelopes beyond current capabilities by implementing its Energy Deposition technologies in collaboration with Texas A&M University's National Aerothermochemistry Laboratory on independent AFRL, NASA and U.S. Navy programs.

Pressure gain combustion gains advocacy

by Christopher Brophy and Dan Paxson

The ***Pressure Gain Combustion Program Committee*** *was established in January 2014 and has 38 members, 10 of whom are international, with membership evenly split among government, industry and academia. The committee advances the investigation, development and application of pressure-gain technologies for improving propulsion and power generation systems and achieving new mission capabilities.*

Interest in pressure gain combustion over the decades has included the investigation of pulse detonation engines, internal combustion wave rotors, pulse combustors, rotating detonation engines and other concepts. Continued strong interest was seen in 2014, with significant research initiatives and a lively discussion over standards and definitions.

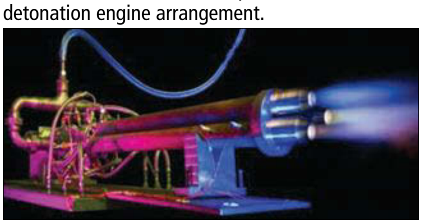
The program committee's working definition of pressure gain combustion — "A periodic combustion process whereby the total pressure of the exit flow, on an appropriately averaged basis, is above that of the inlet flow" — generated healthy discussion in the committee and continues to be debated and modified.

Another challenge will be to define a standard for how the pressure gain delivered in a combustor should be measured, computed and reported. An effort is underway to consolidate the thermodynamic arguments and establish a consistent explanation for how these systems operate and how performance benefits should be calculated.

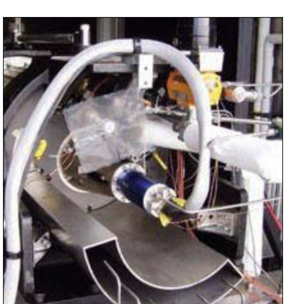
In the science and technology realm, work has been undertaken by private sector organizations and U.S. government agencies, including the Air Force Research Laboratory; Office of Naval Research; the Energy Department's ARPA-E organization (Advanced Research Projects Agency-Energy) and the National Energy Technology Lab. Various combustor architectures have been explored to utilize the thermodynamic benefits of a PGC cycle in which generation of a net pressure rise is seen during a combustion event. A significant amount of recent work has focused on **rotating detonation engines** due to their relative simplicity and potential integration synergy with other propulsion and power subsystems. At the Air Force Research Laboratory, RDE rocket research continued through follow-on programs as well as a new fundamental rocket performance effort. Air-breathing RDE work included integration of an RDE combustor with a conventional turboshaft.

In September, Aerojet Rocketdyne concluded a project to research **continuous detonation combustion** technology as a means of reducing natural gas consumption and greenhouse gas emissions. The project, funded by ARPA-E, was performed at this stage with hydrogen-air and hydrogen-oxygen fueled combustion rather than natural gas.

A General Electric three-tube pulse detonation engine arrangement.

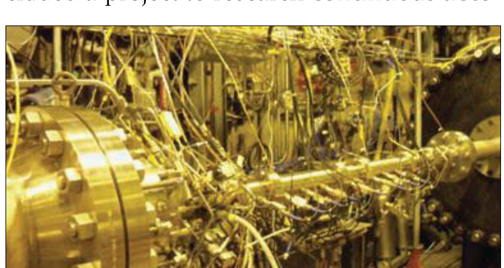


General Electric



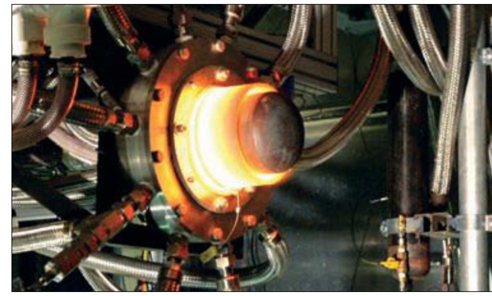
Rolls-Royce/Indiana University-Purdue University Indianapolis

An internal combustor wave rotor developed by Rolls-Royce and Indiana University-Purdue University Indianapolis.



Pratt & Whitney/United Technologies Research Center

A pulse detonation engine developed by the Pratt & Whitney/United Technologies Research Center demonstrates pressure gain at turbine conditions.



AFRL

A rotating detonation engine operating to thermal equilibrium at the Air Force Research Laboratory.

Also in September, the Energy Department's **Office of Fossil Energy** made two Phase 1 awards in the PGC area. Aerojet Rocketdyne will develop and validate a systems model for a rotating detonation combustor suitable for integration into an overall systems model of a power plant, and the company will define the path to configurations exceeding 65 percent combined cycle efficiency. Under the second award, United Technologies Research Center will develop a combined cycle systems model that incorporates pulse detonation combustion. The award includes the conceptual design of modified systems components and pulse detonation technologies and an assessement of multi-stream, kinetics-based NOx production.

In April, the Office of Fossil Energy released a funding announcement, "Advanced Turbine Components for Combined Cycle and Supercritical CO2 Based Power Cycle Applications," for research toward a 65 percent or greater combined cycle efficiency, a 20 percent reduction in cost of energy and a reduction of CO2 capture costs to $40 per metric ton. The Advanced Combustion Turbines topic area included a specific subtopic on PGC systems.

The Office of Fossil Energy has also provided funding to support the fabrication of an RDE design that was scheduled for testing in December. This research effort, which is scheduled to grow in 2015, will continue to explore unique opportunities for PGC in land-based power generation applications, and in close collaboration with colleagues at the Defense Department and NASA.

A Space Act Agreement was established between NASA's Glenn Research Center and AFRL to perform RDE modeling and experimental validation.

The race to reusability

by Adam Dissel and Barry Hellman

*The **Reusable Launch Vehicles Program Committee** brings together experts to focus on leading-edge programs and developments in this area.*

Multiple development efforts are underway to achieve affordable, responsive spacelift and to address current budget pressures and launch market challenges. Interest in reusable launch vehicles as a solution to these challenges remains strong and the past year has seen marked progress by government and industry toward development of reusable spacelift and flight demonstrator systems.

In July, DARPA announced the start of work under the **Experimental Spaceplane** program, called XS-1, which seeks to develop a reusable, responsive first stage launch vehicle. The goal is to break the cycle of escalating space system costs and enable routine space access. Three Phase 1 awards were made earlier in the year to teams headed by Boeing, Northrop Grumman and Masten Space Systems.

Swiss Space Systems is moving forward with its **Soar** three-stage launch system development. The Soar concept is to use an airliner to air launch a reusable rocket-powered shuttle with an expendable final stage. In addition to its new U.S. headquarters in Washington, D.C., S3 opened offices at the Kennedy Space Center, Florida, and at NASA's Ames Research Center in California in preparation for a zero gravity commercial flight campaign with its first-stage Airbus aircraft and for Mach 0.8-2.8 wind tunnel tests on a 1:44 scale mock-up of the shuttle. Additionally, an agreement was signed with the city of North Bay and Canadore College's School of Aviation Technology in Ontario, Canada, which will support S3's 3:8 scale mock-up helicopter drop tests planned for late 2014 and early 2015. A preliminary design review is scheduled for the end of the year.

Virgin Galactic said it would continue with plans to offer suborbital tourist flights after a catastrophic test Oct. 31 when its **SpaceShipTwo** space plane broke up in flight and crashed in the Mojave Desert, killing one pilot and injuring the other. The breakup occurred shortly after the vehicle was released from the WhiteKnightTwo carrier aircraft. In November the company said construction of a second SpaceShipTwo is 65 percent complete. Virgin Galactic is also developing the LauncherOne system to address the small-lift orbital market by using the WhiteKnightTwo to release an expendable launch vehicle.

Generation Orbit is designing a small spacelift system in which an expendable rocket launcher is air-dropped from an executive jet carrier aircraft. The single-stage **GOLauncher 1** will support suborbital research projects while the two-stage GOLauncher 2 will launch small orbital payloads. In July the company completed captive-carry flight tests of a simulated launch stack on a Learjet carrier aircraft.

XCOR Aerospace is moving forward with development of the **Lynx** reusable suborbital space plane. The Lynx Mark I vehicle is expected to be ready by the end of 2014 and begin flight testing in early 2015. Once operational, the Lynx is expected to make multiple suborbital trips a day. Follow-on Lynx versions are being pursued to address small payload orbital flights.

SpaceX has moved into the next phase of testing for the development of a reusable **Falcon 9** first stage after completing eight flight tests of its Grasshopper vehicle. Two F9R airframes were available for testing. In August, a problem shortly after launch caused the first test vehicle to self-destruct on its second test flight in Texas. SpaceX has also completed several downrange landing tests of the first stage of its operational Falcon 9 system.

British company Reaction Engines Ltd. is continuing development of **SABRE**, its Synergetic Air-Breathing Rocket Engine, and entered a cooperative research and development agreement with the U.S. government to perform SABRE cycle analysis and assessment of applications toward future reusable launch systems. ⩓

ESA

Reaction Engine's Skylon concept highlighting the SABRE engine.

The Soar shuttle is carried by a modified airliner.

Swiss Space Systems

Space environment milestones

by Brian O'Connor and the Space Environmental Systems Program Committee

The ***Space Environmental Systems Program Committee*** *focuses on environmental and thermal control technologies for aircraft, spacecraft and exploration missions.*

Notable accomplishments this year in the implementation of environmental and thermal control in aerospace systems included many large projects meeting major review and integration milestones.

In July, NASA's Goddard Space Flight Center completed thermal vacuum testing of the **Magnetospheric Multiscale Mission** observatory satellites at the Naval Research Laboratory. The primary goal was to demonstrate repeated system-level performance at the extremes of the flight predicted temperatures. Vertex Aerospace, contracted by Goddard, developed the thermal design and predicted the flight and test temperatures. In addition, the project designed and implemented 1-Wire temperature sensor technology, which reduced the number of wires from hundreds to just 18. The test demonstrated that the workmanship of the observatories was acceptable. The post-test correlated thermal model verified the effectiveness of the thermal design elements, including surface coatings, multilayer insulation, heater circuit capacities and power duty cycles. The project is scheduled to launch from Kennedy Space Center in March.

ESA

European Space Agency's ExoMars Rover.

The four Magnetospheric MultiScale Observatory satellites are shown fully stacked without covers.

NASA/Barbara Lambert

The **James Webb Space Telescope** achieved a major milestone this year when the **sunshield** was stacked and unfurled in a cleanroom at a Northrop Grumman facility in Redondo Beach, California. The telescope will rely on the sunshield to keep the optics cold. It is about the length of a tennis court when deployed but must be folded around the telescope before launch. Composed of five layers of thin membrane, the sunshield must unfurl reliably in space to precise tolerances to allow the telescope optics to operate at temperatures of around 50 kelvins (minus 370 degree Fahrenheit). The telescope is scheduled to launch in 2018.

The European Space Agency's **ExoMars** mission reached several major hardware delivery milestones this year and is well on its way to a January 2016 launch. The mission consists of an orbiter and a stationary lander. Manufacturing of the back and front heat shield structures was completed by Thales Alenia Space of France and Airbus Defence and Space of Spain, respectively. Both sections were delivered to Airbus Defence and Space in France and 180 cork tiles were bonded to the thermal protection system. Thales Alenia Space also begun integration of the avionics on the lander in Italy. This includes qualifying and installing thermal capacitors needed for the thermal control of some high dissipating avionic units.

ESA's **Orion Service Module** completed its preliminary design review this year. The module will provide primary power, expendable supplies, including water and oxygen, propulsion, attitude control and thermal control to the Orion Multi-Purpose Crew Vehicle. The review inspected the environmental control and life-support system architecture in terms of mass, power and safety aspects of a crewed system. This led, in particular, to improvements in the robustness and reliability of the thermal control subsystem and the consumables subsystem, while minimizing mass.

The expanding field of smallsats, cubesats and microsats is providing an economical platform to test new **thermal control technologies**. For example, the Japanese micro-satellite Hodoyoshi-4, which launched in June, has a number of new technologies that were demonstrated to work in space. One technology is a heat storage panel that moderates temperature changes around the phase-change temperature of a chosen phase-change material, such as eicosane, encased in a carbon fiber reinforced polymer. Another heat storage technology uses a solid-solid crystalline structure change to store the heat. The material could potentially be used in the structure of a spacecraft.

Human, robotic exploration make strides

by Chris Moore and Surendra Sharma

*The **Space Exploration Program Committee** brings together experts on topics relevant to future human and robotic exploration missions.*

NASA announced in January that **International Space Station** operations will be extended through 2024 to allow more time to conduct human research in microgravity and test critical exploration technologies, such as life support systems, to reduce the risks for long-duration missions. To ensure continuity of ISS operations for the next decade, NASA selected Boeing and SpaceX to provide commercial crew transportation services to ISS starting in 2017.

The first test flight of Lockheed Martin's **Orion** deep-space crew capsule is scheduled for December aboard a Delta 4 rocket. The primary objective of the unmanned mission is to test Orion's heat shield. After two orbits, Orion will re-enter the Earth's atmosphere at almost 20,000 miles per hour.

NASA made progress on the **Asteroid Redirect Mission** to capture a small near-Earth asteroid and redirect it into a stable orbit around the moon, where astronauts launched aboard Orion will visit it around 2025. A mission formulation review was completed in April and several candidate asteroid targets were identified. NASA awarded 18 contracts for industry-led studies of asteroid capture systems, rendezvous sensors and a solar electric propulsion module based on an existing commercial spacecraft bus. A subscale inflatable asteroid capture system was designed and tested, a modified space suit for exploring the asteroid was demonstrated in underwater tests, and a new portable life support system for the suit was tested with a human in the loop.

In robotic space exploration, in December 2013 China became the third nation to soft land a spacecraft on the moon. The **Yutu rover** deployed on the Chang'e 3 mission survived for one lunar night at its landing site in the Sinus Iridum crater.

On Mars, NASA's **Curiosity rover** completed its first Martian year (687 Earth days) of operations on June 24. One of Curiosity's first major findings was an ancient riverbed at its landing site, known as Yellowknife Bay, in Gale Crater. The analysis of samples obtained from two mudstone slabs revealed that crater was once a lakebed with mild water and was habitable for simple life forms. **MAVEN**, the Mars Atmosphere and Volatile Evolution spacecraft, went into orbit around Mars in September on a mission to study the evolution of the planet's upper atmosphere.

The **InSight** mission, to be launched in 2016 to investigate the inner structure of Mars' core, mantle and crust, completed its critical design review in May. And in July, NASA announced the seven instruments selected for the Mars 2020 rover, which will search for habitable environments and cache samples for eventual return to Earth. One of the payloads will demonstrate the production of oxygen from the Mars atmosphere to enable in-situ propellant production for human missions.

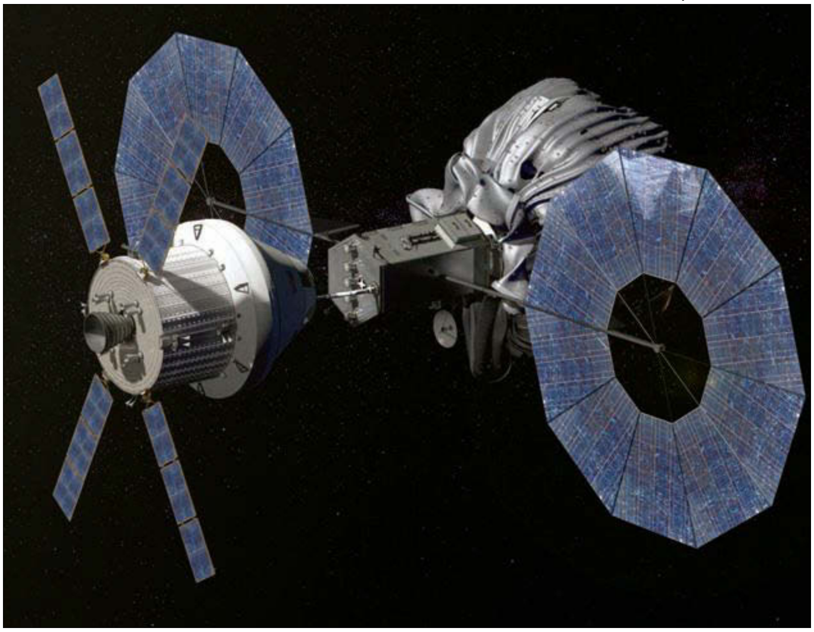
After a 10-year, 6.4-billion-kilometer journey, the European Space Agency's **Rosetta** became the first spacecraft to rendezvous with a comet when it reached 67P/Churyumov-Gerasimenko. Rosetta deployed the Philae lander, which touched down on the comet on Nov. 12 to image and sample the comet's nucleus.

NASA's Pluto-bound **New Horizons** spacecraft, launched in January 2006, has crossed the orbit of Neptune, nearly 2.75 billion miles from Earth, on its way to make a close encounter with Pluto in July 2015. In space exploration technology, NASA tested a prototype low-density inflatable decelerator and 33.5-meter supersonic ring sail parachute for landing heavier payloads on Mars. The test vehicle was dropped from a high-altitude balloon.

Morpheus, a vertical-takeoff-and-landing planetary lander, demonstrated an autonomous landing and hazard avoidance system in flight tests at NASA's Kennedy Space Center.

In August, a 5.5-meter diameter composite cryogenic fuel tank filled with 30,000 gallons of liquid hydrogen completed structural loads tests at the Marshall Space Flight Center. The project is exploring the use of composite materials to produce lightweight fuel tanks for rockets. ▲

This conceptual image shows the Orion spacecraft approaching the robotic asteroid capture vehicle.



NASA

Electric aircraft head to market

by Brian German and Mark Moore

*The **Transformational Flight Program Committee** was established in 2013 to explore the potential of electric propulsion and autonomy technologies on enabling new aviation missions and markets.*

This year saw continued advancements in electric-powered flight. Pipistrel achieved first flight of its WATTsUP electric trainer aircraft in August. The aircraft, which is based on the airframe of the Slovenian company's Alpha Trainer, employs an **85-kilowatt electric motor** developed by Siemens that provides more power than the Rotax 912 it replaces, permitting an increase in the rate of climb to 1,000 feet per minute. The aircraft achieves one hour of endurance with a 30-minute visual flight rules reserve. On approach, up to 13 percent of the energy expended in the pattern climb and circle can be recovered from the windmilling propeller. The three batteries can be removed and exchanged or recharged to 80 percent capacity in less than an hour to enable rapid sorties. The aircraft has been certified in France and preparations are being made for U.S. certification through revised light sport aircraft standards that permit electric motor propulsion. Priced at $125,000, sales are set to begin in 2015.

Airbus flew the E-Fan electric aircraft demonstrator in March. The E-Fan's two motors, powered by a **250-volt battery system**, produce 60 kilowatts of total power for a one-hour flight duration with 15 minutes of reserve. A drive system in the wheels provides 6 kilowatts for taxi and to assist in takeoff acceleration. Airbus said the company will begin producing the E-Fan 2.0 in late 2017 as a certified two-seat pilot trainer and will begin development of a hybrid-electric four-seat aircraft, the E-Fan 4.0, to be certified by 2019 for the general aviation market. These efforts are envisioned by Airbus as prerequisites for application of electrical propulsion technologies in a 90-seat electric or hybrid-electric regional transport.

The Solar Impulse 2 made its first flight in Switzerland in July to prepare for an around-the-world attempt in 2015. The aircraft has a span of 236 feet, which enables placement of **17,000 solar cells** on the wing upper surface. In addition to providing instantaneous power for the airplane's four propellers, the solar cells will charge lithium-ion batteries to provide power at night and in cloudy conditions. The duration of the planned round-the-world flight will be several weeks.

WATTsUP electric trainer aircraft.

Pipistrel

Airbus Group

E-Fan electric aircraft demonstator.

NASA's Langley Research Center started flying the GL-10 Greased Lightning **distributed electric propulsion** sub-scale demonstrator in August. NASA hopes to achieve a factor of four improvement in cruise aerodynamic efficiency compared with existing helicopter-based vertical-takeoff-and-landing operations. The GL-10 is a tilt-wing and tilt-tail configuration with a total of 10 propellers that produce a high induced velocity flowfield over the wing and tail during transition flight to ensure flow attachment and to avoid transition buffet and roll control limitations.

DARPA initiated the Aircraft Labor In-cockpit Automation System, or ALIAS, program in April to provide **enhanced autopilot capabilities** across aviation platforms. The program envisions drop-in equipment kits that serve as full-time automated flight assistants to reduce the required number of crew and pilot workload through trusted and reliable automated systems.

The Transformational Flight Program Committee organized three technical sessions at the AIAA SciTech Forum in January and six at the Aviation Forum in June. Highlights of the sessions included presentations about the Joby Aviation S2 VTOL personal air vehicle concept, papers related to the GL-10 development effort and auralizations of the acoustics of NASA's LEAPTech 20-propeller distributed propulsion concept. Additionally, in partnership with the AHS Advanced Vertical Flight and the AIAA V/STOL technical commitees, the TFPC helped organize the Transformative Vertical Flight Concepts Workshop held in Arlington, Virginia, in August. This event brought together 100 participants from startup companies, large aerospace firms, government and academia to discuss electric propulsion concepts for VTOL aircraft.

The quest for fuel efficiency

by Dyna Benchergui

The ***Air Breathing Propulsion Systems Integration Technical Committee*** *focuses on the application of mechanical design, fluid mechanics, and thermodynamics to the science and technology of air vehicle propulsion and power systems integration*

An MIT/Aurora Flight Sciences/Pratt & Whitney team completed NASA-sponsored experimental and computational studies to assess the boundary layer ingestion, or BLI, benefit on the **MIT N+3 D8** double bubble configuration being considered for 2035-era aircraft. A 1/11th scale powered model investigation in the NASA Langley Research Center 14-by-22-foot subsonic wind tunnel showed a 6 percent reduction in power required, at a simulated cruise condition, for a twin-engine integrated BLI configuration, compared with a podded-engine configuration. Both force and moment data and engine inlet and exit pressure rake flow surveys were conducted to support the assessment of the BLI benefit.

A collaborative Airbus/Snecma study concluded that the **counter-rotating open-rotor engine** is the most fuel efficient option to power 2030-era short- to medium-range airliners. Following CROR blade set wind tunnel testing last year, Snecma is developing a geared open-rotor demonstrator engine to be ground tested by 2015. Airbus is completing engine-airframe integration to meet certification noise and blade-off requirements. Preliminary results indicate a feasible noise level for pusher open-rotors mounted on the aft fuselage and tail, relative to underwing-mounted engines. Airbus is also working to minimize the added weight and fuel burn penalty resulting from using a fail-safe engine hub and airframe shielding to protect the aircraft from blade-off damage.

GE Aviation

A cross-section of the 777X GE9x engine.

As part of NASA's Environmentally Responsible Aviation program, Virginia Tech developed a novel method of designing **distortion tolerant fans** for next-generation aircraft configurations. A target flow distortion pattern, generated experimentally or through computational fluid dynamics, is used to design the **StreamVane**. Subscale models are then wind tunnel tested before full-scale StreamVanes are rapidly produced by additive manufacturing. Particle image velocimetry measurements during initial testing of a 21-inch-diameter StreamVane installed in Virginia Tech's JT-15D research engine showed the desired swirl flow patterns between the StreamVane and fan face. Future work will involve complete mapping of the flow and fan response to the distorted inflow.

The Boeing 787 ecoDemonstrator flight test program is evaluating an acoustically treated oxide ceramic matrix composite, or CMC, nozzle developed by Boeing, Rolls-Royce, COI Ceramics and Albany Engineered Composites. Preliminary test results show that the CMC nozzle's material is more heat resistant and noticeably lighter than state-of-the-art engine nozzles and a potential breakthrough technology for improving propulsion system efficiency.

The GE Aviation **GE9X** engine for the new Boeing 777X is undergoing technology maturation tests, including universal propulsion simulator fan performance tests and CMC parts testing in a GEnx engine.

In the electric propulsion sector, Bombardier demonstrated a non-temperature restricted bleedless auxiliary power unit, or APU, using a starter generator — a first in the aerospace industry. The Safran-developed electric-APU system consists of a starter generator, power electronics and a lithium-ion battery system. The test conducted at Turbomeca's cold chamber facility consisted of a cold soak of the e-APU at minus 40 degrees Fahrenheit, followed by unrestricted starting enabled by its lithium-ion battery system.

Airbus flew the all-electric two-seat **E-Fan** trainer, powered by lithium batteries and an electric motor. The company also began a three-year research project with Hydrogen South Africa Systems to study hydrogen fuel cells to replace APUs for emission-free and low-noise ground operations.

Solar Impulse 2 flew for the first time. The aircraft will be used in 2015 to attempt the first around-the-world solar-powered flight. The propulsion system consists of 17,000 solar cells charging 260 watt-hour per kilogram lithium batteries driving four 17.5 horsepower brushless electric motors.

Under the Air Force Research Laboratory's **ADVENT** program, for Adaptive Versatile Engine Technology, GE completed 100-hour testing of its ADVENT demonstrator and will continue to mature its adaptive cycle design through the follow-on AFRL Adaptive Engine Technology Development program.

In the rotorcraft propulsion sector, GE continued development of technologies for a 5,000-10,000-shaft-horsepower-class turboshaft/turboprop engine under the Army's **Future Affordable Turbine Engine** program. Rig tests will be conducted to validate innovative, advanced components, leading up to a full system demonstration. GE and the Army completed the second test of the GE3000 turboshaft engine, designed as a drop-in replacement for the T700 currently powering UH-60 Black Hawk and AH-64 Apache helicopters.

Power system milestones

By Barbara McKissock and Gregory Carr

*The **Aerospace Power Systems Technical** Committee focuses on the analysis, design, test or application of electric power systems or elements of electric power systems for aerospace use*

In June the **Cassini mission** marked 10 years of exploring Saturn, its rings and moons. Its radioisotope thermoelectric generators are performing as predicted, with propellant as the life-limiting factor of the mission. It is a project of NASA, the European Space Agency and the Italian Space Agency, and is managed by the Jet Propulsion Laboratory for NASA.

MESSENGER, the Mercury Surface, Space Environment, Geochemistry and Ranging mission, marked 10 years since its August 2004 launch and more than three Earth years (14 Mercury years) in orbit. The spacecraft operates in one of the most challenging and demanding environments with solar arrays designed for the high solar intensity (11 suns) and high temperature by tilting the panels as the solar intensity increases. The Johns Hopkins University Applied Physics Laboratory built and operates the spacecraft and manages the mission for NASA.

In another milestone, NASA's Opportunity Mars rover reached 10 years of operation and now holds the **off-Earth roving distance record** of 40 kilometers. Opportunity's power system uses triple junction solar cell technology and a rechargeable lithium-ion battery. The Jet Propulsion Lab manages the project for NASA.

NASA, ATK Space Systems and Deployable Space Systems Inc. are developing **lightweight solar arrays** with innovative packaging and deployment schemes for high-power solar electric propulsion systems. Twenty-kilowatt-scale units of ATK's MegaFlex and DSS' Mega-ROSA were built and tested in 2014. Testing included thermal-vacuum deployment at the Glenn Research Center's Plum Brook Station and Boeing's El Segundo, California, facility; plasma environment testing at JPL; and radiation testing at NASA's Goddard Space Flight Center, along with stowed and deployed dynamics testing, deployed strength and stiffness testing, and analytical correlation to structural and thermal data.

Engineers at NASA's Marshall Space Flight Center, working with Jacobs Engineering and ManTech International, built and tested a large, **inflatable solar array** that could provide 1 kilowatt in Earth orbit. The solar array could be folded and deployed without damaging the solar cells in a laboratory environment.

A **non-nuclear power conversion** demonstration unit for a large fission reactor power system was tested at full power before delivery in September to Glenn. It uses a 12 kilowatt-electric Stirling developed by Sunpower Inc. and features a unique sodium-potassium heat exchanger integrated with a pumped sodium-potassium heat transfer loop developed by NASA's Marshall Space Flight Center.

NASA is developing more efficient **thermoelectric technologies** that can increase performance by two to four times over state-of-practice systems with a 25 percent improvement in electrical power output at beginning of life over the current thermoelectric system operating on Mars and reduced performance degradation over time. Several advanced high-temperature thermoelectric materials and high-temperature rare earth compounds have been developed for integration into advanced power generation devices at JPL. The stability of their thermoelectric properties has been demonstrated for over 18,000 hours at temperatures up to 1,323 kelvins. Teledyne Energy System Inc. will mature JPL's lab scale thermoelectric materials, components and couple production processes into flight-like ready couples and modules.

NASA

Sunpower's 12 kilowatts-electric power conversion unit with electrically heated heater head.

A 1 kilowatt non-flow-through polymer electrolyte membrane fuel cell developed by NASA with Infinity Fuel Cell and Hydrogen Inc. was integrated and tested in a rover power module. It eliminates the mass, volume and parasitic power penalties associated with water management in conventional fuel cells.

NASA is researching the use of high-temperature solid oxide fuel cells that could use hydrocarbon boil-off, residuals and methane that reduce the need for pure hydrogen and oxygen and large waste heat rejection systems.

Expanded power for electric propulsion

by Wensheng Huang

*The **Electric Propulsion Technical Committee** works to advance research, development and application of electric propulsion for satellites and spacecraft.*

This year has seen a renewed push in the operating power of electric propulsion devices, toward both the low and high ends of the scale. A rise in **CubeSat** propulsion demands and funding opportunities, including many from the NASA Small Spacecraft Technology Program, has led to a plethora of new development projects in micro-electric propulsion.

Universities and commercial entities alike are in a race to provide capable, affordable propulsion for small satellites. In particular, Busek Co., the Massachusetts Institute of Technology and NASA's Jet Propulsion Laboratory are developing the next generation of **micro-electrospray thrusters** with operating powers ranging from 2 to 10 watts. Meanwhile, another set of Busek colloid thrusters is expected to fly on the Space Technology 7 Disturbance Reduction System mission in 2015. Michigan Technological University is developing a new electrospray concept based on ferrofluid that can maintain emission tips by a simple application of the magnetic field. The University of Michigan is developing a novel 10-to-50-watt helicon thruster called the CubeSat Ambipolar Thruster and ran a successful Kickstarter campaign to help fund the development.

Busek

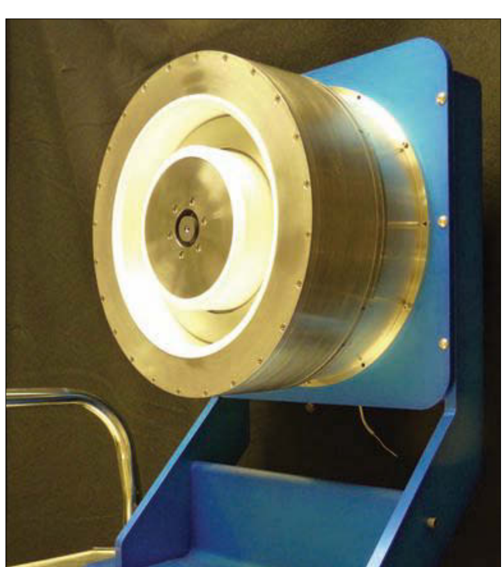
University of Michigan

CU Aerospace

GWU

A collection of micro electric thrusters. Clockwise from upper left: Prototype CubeSat Ambipolar Thruster, Iodine compatible BHT-200 Hall thruster, Propulsion Unit for CubeSat, Micro-cathode arc thruster.

CU Aerospace and VACCO Industries have built and delivered four Propulsion Units for CubeSat systems, which are 15-watt warm gas thrusters, to the Air Force for a 2015 CubeSat launch. George Washington University and NASA Ames Research Center are developing a micro-cathode arc thruster system and plan to deploy it using a PhoneSat bus from the International Space Station in 2015. In addition, Busek is developing two sizes of iodine-compatible micro-RF ion thrusters and **Hall thrusters** for CubeSat and small satellite missions.



NASA Glenn Research Center

A 12.5-kilowatt magnetically shielded technology demonstration Hall thruster.

CubeSat and small-satellite mission designers will be glad to hear that there is no shortage of propulsion options in production.

In the development of high-power electric propulsion, a 12.5-kilowatt, 3,000-second, magnetically shielded technology demonstration Hall thruster, jointly developed by NASA's Glenn Research Center and JPL for the Solar Electric Propulsion Technology Demonstration Mission project and the Asteroid Redirect Mission, was operated at Glenn in August. With a predicted throughput of 3,300 kilograms, this thruster is expected to push several boundaries of high-power electric propulsion. At the same time, Glenn and JPL are studying the possibility of a magnetically shielded variant of the 3.9-kilowatt High Voltage Hall Accelerator, or HiVHAc. Glenn has concluded the life test of the 6.9-kilowatt NASA Evolutionary Xenon Thruster at 51,184 hours and 35.5 meganewton-seconds, which are world records for electric propulsion testing. Space Systems/Loral is qualifying the 4.5-kilowatt SPT-140 for use on a new high-power propulsion system with an ongoing life test that has exceeded 6,000 hours. Boeing is on track to produce the 702SP, the world's first **all-electric-propulsion satellite**. Snecma is pushing the operating power of the PPS-1350 Hall thruster from 1.5 kilowatts up to 2.5 kilowatts by performing a new qualification program while developing the 5-kilowatt PPS-5000.

Australian National University developed a new test facility, called the Wombat XL, for helicon thrusters and high-power plasma devices. MSNW of Redmond, Washington, is qualifying 1-to-5-kilowatt power processing modules for rotating magnetic field propulsion systems. Last but not least, the University of Michigan is pushing the Hall thruster power boundary with the 100-kilowatt X3 nested-channel Hall thruster.

The ion-thruster-propelled **Dawn spacecraft** is cruising to the dwarf planet Ceres, with a planned arrival date in March. Hayabusa-2, also propelled by ion thrusters and successor to Hayabusa-1, is slated to launch at the end of 2014 to rendezvous and sample an asteroid.

With each new success, electric propulsion becomes more widely accepted and newer boundary-pushing electric rockets can be developed, paving the way for even greater successes.

Testing drives gas turbine advances

by Robert S. Webster

*The **Gas Turbine Engines Technical Committee** works to advance the science and technology of aircraft gas turbine engines and engine components.*

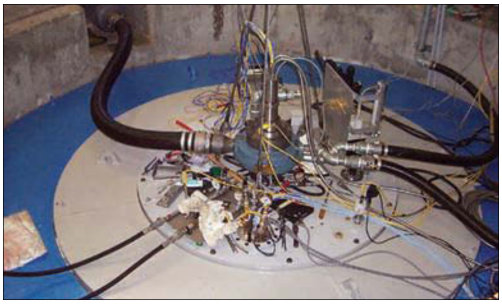
Engine system testing and university component test facilities played important roles in gas turbine engine advance throughout the year.

The Naval Postgraduate School's Turbopropulsion Laboratory advanced a number of critical technologies for gas turbines. These efforts included computational and experimental work on **splittered-rotor transonic fans** to obtain ultra-high single-stage pressure ratios of greater than 2-to-1 at moderate tip Mach numbers. TPL also conducted research on advanced and unique **turbomachines**, such as cross flow fans, for ultra-high lift vehicles, and fluidic control. Work is continuing in the school's spin-pit on methods to excite and measure blade vibrations as well as blade damping techniques.

The Steady Thermal Aero Research Turbine, or **START**, a new gas turbine research lab at Penn State's Mechanical and Nuclear Engineering Department, became fully operational. The lab, which houses a continuous duration flow facility, includes a 1.5-stage test turbine whereby rotational and axial Reynolds and Mach numbers are matched to that of an engine. The goals for the new lab are to improve turbine stage sealing and cooling technologies at a reasonable cost by using engine hardware, evaluate the uses of additive manufacturing and evaluate new turbine instrumentation.

Rolls-Royce announced in July that the first run had been made of its higher-thrust version of the **Trent XWB**. The 97,000-pound-thrust Trent XWB-97 is the only powerplant selected for the Airbus A350-1000 aircraft. The increased thrust is achieved through a combination of new high-temperature turbine technology, a larger engine core and advanced fan aerodynamics. In June it was announced that the first run had been made of the Trent 1000-TEN, which will power all variants of the Boeing 787 Dreamliner. The Trent 1000-TEN draws on technologies from the Trent XWB engine and Advance engine program, delivering thrust and efficiency improvements.

Engine testing by GE Aviation is on schedule for all the **Leading Edge Aviation Propulsion** engine variants, the newest engine from CFM International, a joint venture between GE and Snecma. A total of 20 LEAP engines are on track for testing by year end. GE and the U.S. Air Force Research Laboratory are testing their adaptive cycle engine under the Adaptive Versatile Engine Technology, or ADVENT, program. ADVENT is scheduled to finish this year, logging up to 100 total test hours. GE continues to mature its adaptive cycle design with AFRL through the Adaptive Engine Technology Development program. AETD combustor tests are underway with **3-D printed fuel nozzles** and ceramic matrix composite components. In June, GE and the U.S. Army completed their second GE3000 turboshaft engine test. The GE3000 is designed as a drop-in replacement for the T700 currently powering Black Hawk and Apache helicopters.



Naval Postgraduate School

Spin-pit test facility at the Naval Postgraduate School.

The Williams International FJ44-4A-32, now entering production for the Hawker 400XPR light jet, is a variant of the FJ44-4A engine that powers the Cessna CJ4 as well as the newly announced Pilatus PC-24. And AERO Vodochody recently announced the launch of development of the new L-39NG jet training aircraft. The key feature is the light and fuel-efficient Williams International FJ44-4M engine, which delivers improved performance in speed, range and endurance. The company plans to introduce the prototype in 2016, with the first deliveries in 2018.

Trent XWB engine

Rolls-Royce

Hypersonic research accelerates

by Hassan Hassan, Venkat Tangirala and Dora Musielak

*The **High-Speed Air Breathing Propulsion Technical Committee** works to advance the science and technology of systems that enable supersonic and hypersonic air vehicle propulsion.*

Efforts are continuing in the U.S. and internationally in the development of scramjet technology, with the goal of providing cost-effective hypersonic flight.

One near-term effort underway is the U.S. Defense Department's **High-Speed Strike Weapon** missile. It is expected that scramjet technology will be used to propel an HSSW vehicle similar in size to the 4,000-pound X-51A hypersonic demonstrator to Mach 5 or 6.

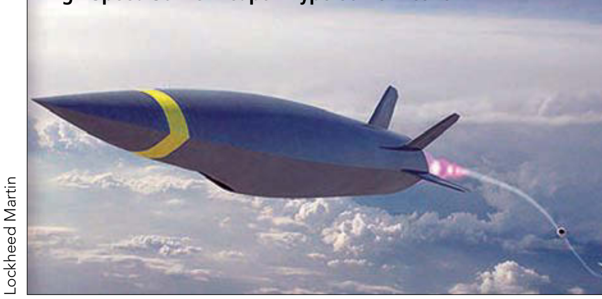
To further enhance understanding of scramjet technology, the Air Force Research Laboratory is constructing a facility with a test section that measures 18 feet in length from the entrance of the isolator to the exit of the combustor, with a mass flow rate 10 times that of the X-51A. The testing will be performed at the Arnold Engineering Development Center in Tennessee. Also this year, AFRL and AEDC established a partnership to launch the **High-Speed Experimentation Branch** at AEDC. The aim of the partnership is to implement the program outlined in "America's Air Force: A Call to the Future," the Air Force's 30-year strategy document, which was released in July. In particular, AEDC, which has unique facilities, will be collaborating with AFRL in the development of the next generation of scramjet engines. The new branch, headed by AFRL high-speed systems science and technology adviser Glenn Liston, will conduct fundamental and systems research in propulsion, aeronautics and structural applications providing technology maturation related to hypersonics.

Under a new Space Act agreement between NASA and the Air Force, NASA will support several Defense Department programs related to hypersonic flight, including medium-scale critical components, the Large-scale Scramjet Engine Test Technique and the High-Speed Strike Weapon program.

AFRL's Aerospace Systems Directorate entered into a cooperative research and development agreement with U.K. aerospace company Reaction Engine Ltd. to assess the performance, applications and development path for the REL **synergetic air-breathing rocket engine**. The agreement will enable AFRL to determine whether the engine will offer unique performance

Mach 4 free-jet experiment of a pre-cooled turbojet engine.

JAXA



High-Speed Strike Weapon hypersonic missile.

Lockheed Martin

and vehicle integration advantages compared with traditional hypersonic engines.

A **pre-cooled turbojet engine** was tested under Mach 4 conditions at the Japan Aerospace Exploration Agency's Kakuda Space Center in February. The engine was placed on the free-jet test stand of the Ramjet Engine Test Facility, where hot and high-speed air at 880 kelvins simulating Mach 4 flight conditions was supplied to the engine. Pressure recovery performance of the air intake and heat exchange performance of the pre-cooler using liquid nitrogen were obtained in the experiment. This is in preparation for a rocket-based combiner cycle flight test.

In-house projects at NASA's Langley Research Center Hypersonic Air Breathing Propulsion Branch included further development of the **VULCAN-CFD** package to allow for vibrational non-equilibrium and additional subgrid scale models, the new Isolator Dynamic Research Lab, and the enhanced injection and mixing project.

The Naval Postgraduate School's Rocket Propulsion Lab has been conducting research into pressure gain combustion. Experimental testing of various rotating detonation engines explored pressure gain combustion characteristics and the associated higher thermodynamic efficiencies using conventional and advanced diagnostics, including high-bandwidth spectroscopy-based sensors.

Finally, 2014 marked the fifth and final year of funding for the **National Center for Hypersonic Combined Cycle Propulsion**. The fifth-year participants included the universities of Virginia, Ohio State, George Washington and North Carolina State, together with NASA's Langley Research Center. Using a dual-mode scram test facility, a variety of test sections and injectors were used, in conjunction with various instrumentation and simulation methods. The net result is that a wealth of data was generated for both unmixed and pre-mixed turbulent reacting flows. LES/RANS simulations were conducted, which showed good agreement with the experiments. ▲

Testing innovative rocket fuels

by Martin Chiaverini

*The **Hybrid Rockets Technical Committee** studies techniques applied to the design and testing of rocket motors using hybrid rocket systems.*

SystemsGo, the educational non-profit organization replicating the successful Fredericksburg High School Aeroscience program across Texas, tested six **free-flight sounding rockets** in July. The six vehicles each used hybrid propulsion systems, and were developed at five high schools in the state. The hybrid propulsion systems used HTPB — hydroxyl-terminated polybutadiene — and paraffin fuels to produce 1,500 to 2,000 pounds of thrust.

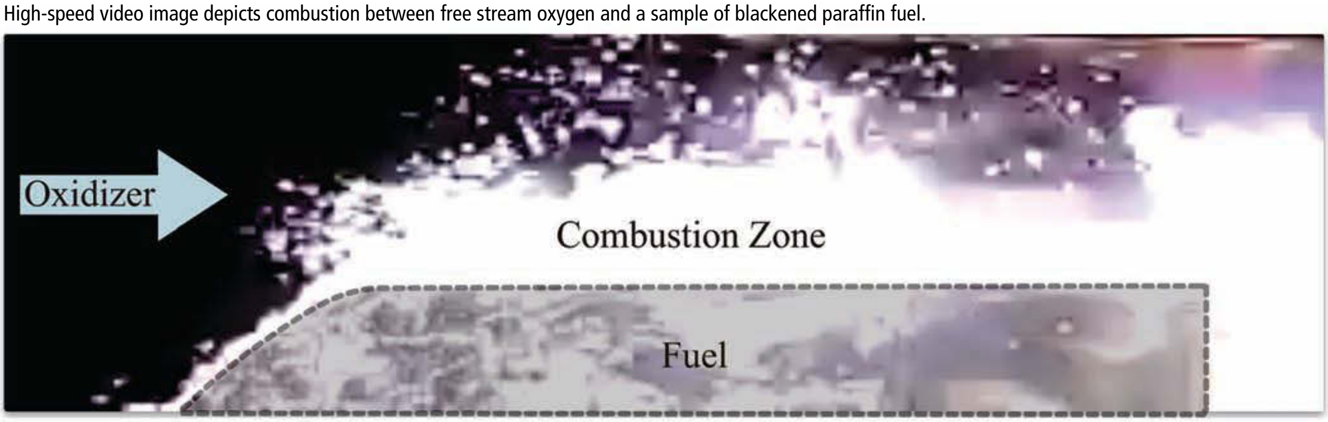
The Utah State Propulsion Research Laboratory tested a unique **low input power arc-ignition system** for hybrid rockets. While investigating acrylonitrile butadiene styrene as hybrid rocket fuel, additively manufactured ABS was shown to possess unique electrical breakdown characteristics. When an electric field is applied to the fuel grain surface, this induces an electrostatic arc, resulting in butadiene vapor that seeds combustion. Multiple prototypes were designed, built and tested. Minimum conditions for successful operation were determined, including minimum ignition pressure, optimal geometry and electrical power requirements. Hands-off restart capability was demonstrated repeatedly on a lab-scale system.

In Japan, the Hybrid Rocket Research Working Group, led by Toru Shimada, conducted static firing tests of a **swirling-oxidizer-flow-type** hybrid rocket engine with a thrust of 1.5 kilonewtons for 20 seconds and with a thrust of 4.5 kilonewtons for 5 seconds. The group conducted a conceptual study on a low-cost, 100 kilogram-satellite launcher using hybrid rocket engines.

The hybrid rocket research group at the Hindustan University in Chennai, India, has developed and tested paraffin-sorbitol-based hybrid fuels. A lab scale motor was tested with gaseous oxidizer. The group is currently working on reaction kinetics of the Paraffin-Sorbitol based hybrid rocket fuel.

Doctoral student and researcher Beth Jens and Professor Brian Cantwell at Stanford University have continued investigations into the combustion of high regression rate and classical fuels using the Stanford Combustion Visualization Facility. They have conducted 29 tests across five different fuels and various operating pressures up to 200 psi. Video data recorded includes high speed schlieren, color video and OH chemiluminescence images. The high-speed video depicts combustion between oxygen in the free stream moving from left to right and a sample of blackened paraffin fuel. The shape of the sample with its streamlined leading edge on the left and blunt trailing edge on the right can barely be discerned through the luminous flame. The image depicts the entrainment of reacting fuel droplets and rapid growth of the combustion layer. The pressure in this experiment was approximately 160 psi and the flow speed was approximately 2 meters per second.

High-speed video image depicts combustion between free stream oxygen and a sample of blackened paraffin fuel.



Beth Jens and Brian Cantwell/Stanford University

Professor Joseph Majdalani of Auburn University taught the AIAA hybrid rocket course this year during the AIAA Joint Propulsion and Energy Forum in Cleveland. The course attracted a strong international presence from Germany, Japan, Italy and South Korea. Majdalani covered all 14 lectures in two full days and was subsequently invited to Japan by Mitsubishi and JAXA, the Japanese aerospace agency, to teach the course.

Majdalani and his student Josef Fleischmann won first place in the AIAA Region 2 competition for their paper on an improved flow duels model for vortex injection hybrid rockets.

Tests signal progress for launch, interplanetary propulsion

by Vineet Ahuja

The ***Liquid Propulsion Technical Committee*** *works to advance reaction propulsion engines employing liquid or gaseous propellants.*

AJ-26 engine firing at the John C. Stennis Space Center's E1 test facility.

NASA

Liquid propulsion developments for 2014 include adaptation of heritage engines, continued development of new engines, testing and certification, as well as advances in sustainable propulsion.

United Launch Alliance and Aerojet Rocketdyne completed development of the RL10C-1 engine, with the first unit installed on a Centaur upper-stage vehicle. For the Fleet Standardization Program, the Aerojet Rocketdyne RS-68A engine was certified for flight on a medium-class Delta 4 launch vehicle.

Under NASA's **Space Launch System** program, Aerojet Rocketdyne's RS-25 engines were adapted for the SLS rocket's core stage. The RS-25 development engine with an updated engine control system is installed at NASA Stennis Space Center in Mississippi for hot fire and system integration testing. Also at Stennis, the Aerojet Rocketdyne J-2X engine completed the final 12 development tests, for a total of 59 tests accumulating over 17,000 seconds of hot-fire time, including two low-power tests at 50 percent of its design power level.

A preliminary design review was completed for the European Space Agency's **Orion Service Module**, which will provide power and propulsion for the Orion crew vehicle after separation from the launch vehicle. The module is being developed under an agreement between NASA and the ESA. The module will provide propulsion with a storable, pressure-fed bipropellant system feeding a 26.6-kilonewton main engine with thrust vector control, eight 490-newton auxiliary engines, and 24 220-newton reaction control system engines.

ESA's Vinci expander cycle engine, developed by Safran/Snecma, demonstrated operation in dual mode with a main boost thrust of 180 kilonewtons and a restart boost thrust of 130 kilonewtons. As part of the ESA's **Future Launcher Preparatory Program**, an Expander Technology Integrated Demonstrator in the 110-150 kilonewton thrust class is being prepared by Airbus Defence and Space. Additive manufacturing is being used to produce the liquid oxygen/hydrogen injector as a single part. A 40-kilonewton prototype injector was tested at the DLR P8 test bench.

Moog's Westcott Operation completed the first phase of an ESA-funded effort to develop the 1,100 newton MMH/MON **LEROS-4 High Thrust Apogee Engine**. The engine would enable increased payloads for ESA's future interplanetary exploration missions by reducing the mass of spacecraft propellant required for orbit insertion maneuvers. More than 700 engine firings were conducted during sea-level testing.

In Japan, IHI Corp. and IHI Aerospace carried out hot fire tests on a 100 kilonewton class liquid oxygen/methane regeneratively cooled rocket engine that has been under development since 2008.

SpaceX's Falcon 9 launch vehicle delivered a satellite to geostationary transfer orbit for the first time with the launch of the SES-8 communications satellite in December 2013. In July, a Falcon 9 powered by an **MVacD** upper-stage engine launched the first six of the new Orbcomm Generation 2 satellites. The MVacD delivers more than 792 kilonewtons vacuum thrust, 339 seconds vacuum specific impulse and a 2.23:1 throttling capability. It also demonstrated the ability to re-start after a long duration coast.

The Air Force Research Laboratory continues making progress on its flagship **Hydrocarbon Boost** program to develop critical technologies for oxygen-rich staged combustion engines. A subscale preburner was tested and the first full-scale component for the system was built.

Also, a new program has been initiated on thrust and combustion stability scaling involving partners from industry and academia.

In sustainable propulsion, through NASA's Green Propellant Infusion Mission, Ball Aerospace is leading a team of Aerojet Rocketdyne, AFRL, and NASA technicians to develop and flight test the **non-toxic monopropellant AF-M315E** as an improved, safer hydrazine alternative. Aerojet Rocketdyne completed hot fire tests on flight representative 1-newton and 22-newton thrusters at its green facility in Redmond, Washington. The plume of the 22-newton lab model thruster was characterized at NASA's Glenn Research Center in Ohio using Raman spectroscopy and schlieren imaging. Similarly, Orbital Technologies developed reaction control thrusters, evolved from heritage designs, to be used on Sierra Nevada's Dream Chaser spacecraft with green propellants. ▲

Sea-level test of a Dream Chaser RCS Thruster in the Orbital Technologies test facility.

Sierra Nevada

Fueling exploration

by Bryan Palaszewski

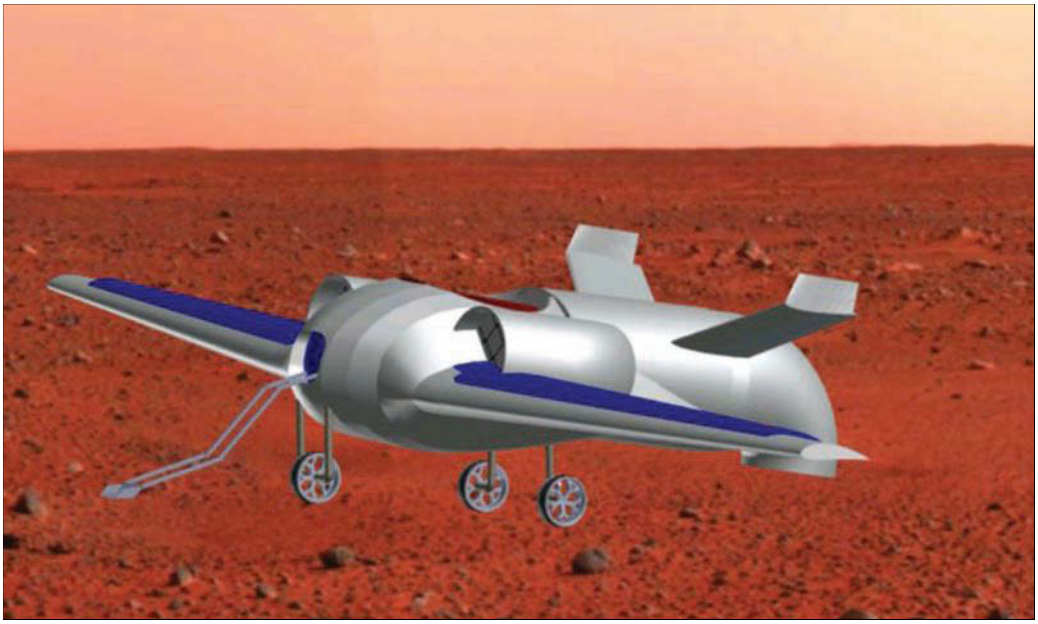
*The **Nuclear and Future Flight Propulsion Technical Committee** works to advance the implementation and design of nonchemical, high-energy propulsion systems other than electric thruster systems.*

NASA's Glenn Research Center has developed preliminary designs for robotic **aerospacecraft**, powered by gas core nuclear rocket engines, that would mine helium 3, helium 4 and hydrogen from the atmospheres of Uranus and Neptune to make fuel for smaller unmanned exploration aircraft. A study of aerial vehicle reconnaissance and exploration options was presented at AIAA Propulsion and Energy 2014 in July.

Mission analyses for the exploration vehicles assessed one-way, round-trip, multiple observations, loitering at a phenomenon of interest and other options. Unmanned aircraft designs that would accommodate both short and long missions were proposed. The times to travel between various areas of Uranus and Neptune were assessed, including distances of 10 to 90 degrees (latitude or longitude) and using aircraft velocities of 100 to 400 meters per second. For Uranus, it would take approximately 111.5 hours to traverse 90 degrees at 100 meters per second. At 400 meters per second, the travel time would be 27.9 hours. The travel times at Neptune would be slightly lower, given the planet's slightly smaller diameter. For example, at Neptune, a flight at 100 meters per second for the 90-degree traverse would be 108.1 hours; the time to traverse 90 degrees at 400 meters per second would be 27 hours.

For an unmanned aircraft observing a storm, circumnavigating the entire storm is an advantageous approach that would enable detailed studies of anomalous behavior, winds or other unique features. Time for circumnavigation of storms was computed and included a 100-kilometer standoff distance from the edge of a circular storm. At an unmanned aircraft speed of 300 meters per second, the time to circumnavigate a 0.05 Earth radius storm (319 kilometers in diameter) is just under 91 hours. These analyses suggest that there may be several avenues for using the gases of the outer planets effectively on future exploration missions. The vast reservoirs of fuels at Uranus and Neptune are more readily accessible than those at Jupiter and Saturn and, with the advent of nuclear fusion propulsion, may offer the best option for the **first practical interstellar flight**.

The University of Miami conducted a preliminary feasibility study for a proposed multimission Mars explorer craft — the Mars Aerial Nuclear Global Landing Explorer, or **MANGLE**. Using nuclear propulsion to fly in the Martian atmosphere, this aerial and land robotic system would take off and land vertically. The craft would use the planet's atmosphere, which is mostly carbon dioxide, as propellant for an air-breathing engine heated by a fission nuclear reactor based on an open Brayton cycle. To achieve vertical takeoff and landing the craft would use a lifting fan and the vectored nozzle of the engine. The engine would generate both thrust and auxiliary power. MANGLE would cruise at Mach 0.4. The engine's power requirements would be 2.1 megawatts at takeoff and landing, and 0.4 megawatts at cruise. The system's total mass would be 899 kilograms.



AIAA

This artist's rendering depicts the Mars Aerial Nuclear Global Landing Explorer taking a soil sample.

The craft's weight is low because it carries no propellant or radiator, and because of the extremely high power and energy density of nuclear fission. MANGLE's blended-wing-body design uses a co-flow jet airfoil. This innovative ultra-high-lift flow control airfoil would provide a cruise lift coefficient of 3.5 — five to 10 times greater than that of a conventional airfoil. MANGLE would not only perform a science mission to investigate the Martian atmosphere, but would also land to examine soil samples at locations of interest observed from the aerial survey.

Game-changing turbulent combustion research

by Chiping Li, Joanna Austin and Yiguang Ju

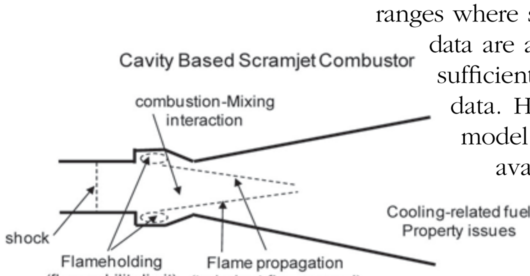
The ***Propellants and Combustion Technical Committee*** *works to advance the knowledge and effective use of propellants and combustion systems for military, civil and commercial aerospace systems.*

Turbulent combustion is the central energy conversion process in most U.S. Air Force propulsion systems, such as jet engines, scramjets and large-scale rockets. In these engines, the fuel/propellant and oxidizer are combusted at highly turbulent conditions and chemical energy is converted to mechanical energy for propulsion. The **turbulent combustion process** determines the engine operability — for example, flammability of recirculating flame-holders — and the efficiency, including turbulent flame speed, flame surface area and overall burning rate.

U.S. Air Force

Over the past 30 plus years, significant experimental data have been gathered for turbulent flames of various jet configurations and in piston engines. However, the turbulence intensity in those experiments is significantly lower than that in jet engines, scramjets and rockets. This is partially due to the experimental and measurement difficulties at the high temporal and spatial resolutions required to study the combustion processes at those highly turbulent conditions. Since 2011, the Air Force Office of Scientific Research has been making significant investments in this area. This was facilitated by game-changing progress in combustion diagnostics from AFOSR's long-term investments, as well as those at Sandia National Laboratories' Combustion Research Facility under support from the Department of Energy. These efforts have already begun to reveal insights of those highly turbulent combustion processes. Using 10 kilohertz hydroxyl planar laser induced fluorescence, James Driscoll and his colleagues at the University of Michigan showed that the **flame surface area** increases significantly as the turbulence intensifies, resulting in a higher overall burning rate. Similar observations have been made from other physical and numerical experiments, such as those at Georgia Tech and Naval Research Laboratory. These results indicate that much more efficient combustion mechanisms can potentially be devised by increasing the turbulent intensity.

Turbulent combustion **modeling and simulation** are playing increasing roles in Air Force engine development, mainly in condition ranges where significant experimental and test data are available and models have been sufficiently tuned and anchored to the data. However, major gaps remain in model validation. Until recently, most available data for validation were collected at relatively modest turbulent intensity, relevant to ground-based systems. As experimental data are becoming available at highly turbulent conditions relevant to aviation and space engines, mostly from efforts supported by the Air Force Office of Scientific Research, validation and comparison efforts at those conditions are now becoming feasible.



It is not sufficient to simply compare global statistical features, such as scalar scatter plots, since very different flame structures of significantly different overall burning rates can result in nearly identical scalar scatter plots. It is also critical to be able to accurately represent off-design engine operations, involving ignition/re-ignition, flame blowout and combustion stability. These state-changing, transient phenomena are statistically rare but operationally consequential. They are often encountered in the development of new, innovative engines and usually not well represented by statistically averaged modeling approaches. In the **model development** process, it is essential to analyze and validate the fundamental model assumptions, based on their representativeness of and consistency to the underlying phenomena to be modeled. Such evaluation procedures are logically far more scientifically rigorous than merely comparing to global statistical features.

Taking advantage of newly available experimental data and working with leading researchers in the community, AFOSR and its partners at the Air Force Research Laboratory's Aerospace Systems Directorate are taking the following steps in turbulent combustion model development:

- Determining dominant/rate-controlling phenomena and processes in relevant regimes and conditions.
- Obtaining fundamental understanding and quantifying data for those phenomena and processes.
- Analyzing key model assumptions based on their representativeness of and consistency to the underlying phenomena and processes to be modeled.
- Using the above results and data as foundations for model development, improvement and validation.
- Constructing validation/verification procedures for evaluating fundamental model assumptions and comparing simulation results of integrated codes to strategically selected experimental and test data.

In the above steps, particular emphasis is given to rate-controlling processes and key performance parameters, especially at conditions where the phenomena/processes change states, such as the engine flammability limit, combustion dynamics and ignition transients. Results from these efforts are becoming available.

Solid rockets score in tests, reach milestones

by Rob Black, Clyde Carr, Mark Langhenry and Barbara Leary

*The **Solid Rockets Technical Committee** works to advance the art, science and engineering of solid rocket propulsion, and to foster dissemination of new knowledge in this field.*

Solid rocket motor technology in tactical, strategic and launch systems saw progress through flight testing, motor demonstrations, production milestones and propellant disposal.

In tactical systems, solid rockets continue to dominate. The **Standard Missile-6** destroyed a supersonic missile target and a long-range cruise missile target in July. The SM-3 Block IB program launched from the new Aegis Ashore weapon system in May. The Raytheon SM-3 and SM-6 both use Aerojet Rocketdyne first- and second-stage motors and an ATK dual-pulse third stage for the SM-3.

Lockheed Martin began production of the **Patriot Advanced Capability-3 Missile Segment Enhancement** motor, which uses an Aerojet Rocketdyne dual-pulse motor. MBDA dual-mode **Brimstone** air-to-surface missiles powered by Roxel motors scored nine direct hits in challenging scenarios in March and then demonstrated the ability to destroy a marine attack craft in a cluttered environment in July.

Milestones were reached with the production of the 3,000th **Tomahawk** Block 4 motor and the 2000th **Griffin** missile, which each use an Aerojet Rocketdyne booster, and delivery of the first Block 2 variant of the Rolling Airframe Missile, which uses an ATK booster.

In the strategic systems area, the **Trident 2 D5** ballistic missile made its 150th flight test in June. The D5 uses ATK-produced first, second and third stages and, from Aerojet Rocketdyne, a post-boost control system and nozzle fairing jettison motors. In February, Aerojet Rocketdyne demonstrated, at simulated altitude, a large (92-inch diameter) second-stage motor using affordable materials and subsystems for the U.S. Air Force.

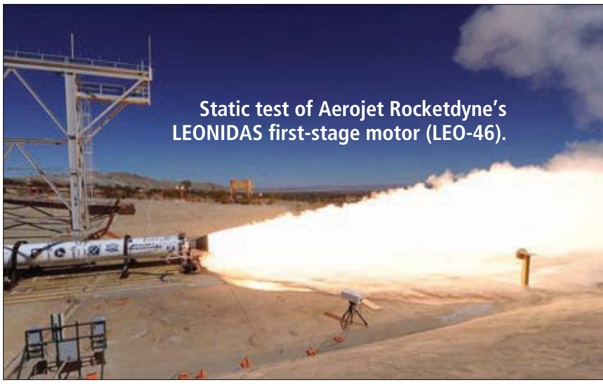
The launch systems area also saw significant progress this year. Arianespace's **Vega** launch system, utilizing three Avio-manufactured solid stages, made its third flight in April. The **Ariane 5** launcher, using two solid boosters built by Herakles (part of the French Safran group), completed its 60th mission. In August, Aerojet Rocketdyne demonstrated the Low Earth Orbiting Nanosatellite Integrated Defense Autonomous System, or **LEONIDAS**, first-stage motor (LEO-46), part of the SPARK — Spaceborne Payload Assist Rocket-Kauai — launch system designed to place miniaturized satellites into low-Earth and sun-synchronous orbits.

The third launch of Vega at liftoff.

Arianespace

ATK's GEM-40 (3) and GEM-60 (4) motors continued to support U.S. Delta 2 and Delta 4 launches for NASA's **Orbiting Carbon Observatory-2** and next-generation GPS-2F satellites. In addition, ATK retro-motors (eight per launch) supported two Atlas 5 rocket launches.

The first flight test of the Jet Propulsion Laboratory's Low-Density Supersonic Decelerator was launched in June from the Pacific Missile Range Facility in Hawaii. ATK's off-loaded **STAR 48B** rocket motor provided the propulsion for the balloon launch, which carried the test vehicle from an altitude of about 120,000 feet to over 180,000 feet. The flight test was designed to simulate the low pressure and punishing speeds experienced by payloads dropped into the Martian atmosphere. ATK and NASA also tested a proof-of-concept **STAR 48GXV** motor using new case and nozzle technologies for the Solar Probe Plus mission, which will enter the sun's atmosphere to study the streams of charged particles the sun hurls into space.



Static test of Aerojet Rocketdyne's LEONIDAS first-stage motor (LEO-46).

Aerojet Rocketdyne

ATK's **CASTOR 30B** upper-stage solid rocket motor flew two payloads on Orbital Science's Antares I rocket to the International Space Station. Future flights will use the newly qualified CASTOR 30XL SRM, which will provide increased payload capability.

In the area of rocket motor disposal, Herakles has built a new facility capable of destroying 300 metric tons of the solid propellant oxidizer ammonium perchlorate. The facility is based on the Herakles patented process that uses bacteria to transform the ammonium perchlorate into nitrogen and chloride and provides an environmentally responsible approach for propellant disposal.

With aid of Dragon, a busy year for life sciences

by Joe Chambliss

*The **Life Sciences and Systems Technical Committee** advances technologies required to keep people healthy and safe as they explore space.*

The life sciences and systems community is actively conducting aerospace-related efforts focused on enabling human exploration of space.

Members worked with the American Society for Gravitational and Space Research to educate Congress about several issues regarding life and physical science research.

The **T-Cell Activation in Aging** experiment, also known as NIH1a for its sponsor the National Institutes of Health, was returned to Earth in May aboard a SpaceX Dragon capsule after a month in orbit. The payload, developed by Kayser Italia for the European Space Agency, investigated the diminishment of T-cell activation in astronauts related to aging. The experiment was refurbished and scheduled to be delivered to the station again on the SpaceX-5 mission in December.

The Italian Space Agency, ESA and NASA have completed an accommodation study to ensure that the space station's **Advanced Resistive Exercise Device**, an exercise machine for ISS astronauts, can be connected to a system called ELITE for the Elaboratore Immagini Televisive, which records the movements of astronauts.

The CELLBOX experiment has been delivered to NanoTacks LCC of Webster, Texas.

An important set of experiments are in preparation for the ESA's Italian astronaut Samantha Cristoforetti.

In August, NASA completed a closed chamber test at the Marshall Space Flight Center to demonstrate operation of the ISS-derived **Atmosphere Revitalization Systems** life support equipment in evolved configurations for the purpose of increasing reliability, reducing mass and improving performance. Preliminary results included an increased reliability of the Oxygen Generation Assembly and reduced system weight, and operational changes show that the Carbon Dioxide Removal Assembly can reduce cabin CO2 levels to a partial pressure of 2 Torr for a four-person crew, compared with the ISS baseline of 3.8 Torr, with configuration and minimum material changes. An advanced Trace Contaminant Control configuration demonstrated the ability to reduce contaminants such as Siloxanes in water condensate to potentially improve performance and longevity of water processor components. The final phase of the test consisted of installing development environmental monitoring equipment from NASA's Jet Propulsion Lab into the E-chamber at NASA's Marshall Space Flight Center, exposing them to elevated levels of selected contaminates and comparing results to laboratory standard equipment. The tests were supported by NASA Ames, the Glenn Research Center, JPL, the Johnson Space Center and the Kennedy Space Center.

The Advanced Exploration Systems Water Recovery Project made advances in development of **water processing technologies** for exploration including testing and design of the Cascade Distillation System — CDS — urine processor prototype 2.0 through preliminary design review, development of less toxic or green urine pre-treatment, design of a urine brine processor and research into the use of silver as a biocide. The team also completed manufacturing a thermoelectric heat pump for the CDS. The heat pump provides heating and cooling for the multistage evaporation and condensation process that the CDS uses to recover purified water from wastewater.

The **Inspiration Mars** concept to send two people on a free-return trajectory around Mars in 501 days ran into political realities of approval on Capitol Hill. This has pushed the mission to adopt a later launch opportunity that stretches the mission duration to 580 days and includes flybys of both Mars and Venus. The 15 percent increase in mission duration makes the Life Support System task even more challenging but still achievable utilizing the existing system architecture and technologies. The IM Life Support technology test bed at Paragon Space Development Corp. was brought online and all primary Inspiration Mars regenerative life support technologies completed one week of bench-top testing to verify performance and readiness to conduct follow-on integrated long-term testing.

As a result of equipment delivered by April's SpaceX-3 Dragon flight, the ISS's powered locker locations have been increased from two to six, and the cold stowage team at NASA Johnson provided a 180 percent increase in the amount of temperature-sensitive science achievable on the station.

The Unmanned Pressure Integrated Suit Test team completed a test series of varying configurations and pressures with the development Orion air revitalization loop and Modified Advanced Crew Escape Suits.

The Orion Environmental Control and Life Support System/Suit Intermediate Pressure Suit Test was completed as part of a series of manned Orion suit loop tests, the first full closed loop test series done since Apollo. The tests incorporated suits modified for Orion launch and entry, as well as new Orion systems.

NASA's Atmosphere Revitalization Systems test chamber is readied for integrated testing.

NASA

Expedition 39 flight engineer and NASA astronaut Steve Swanson activates the Veggie plant growth system and Veg-01 experiment in the ISS in May.

Physical sciences on the ISS

by Brian Motil and Michael Hicks

The ***Microgravity and Space Processes Technical Committee*** *encourages the advancement and public awareness of low-gravity studies in physics, materials, biological sciences, and related fields.*

Research on the International Space Station delivered exciting results this year. In the Combustion Integrated Rack, scientists working on the Flame Extinguishment or FLEX experiment concluded a study on the efficacy of suppressant gases used in spacecraft and on the flammability limits in different normoxic atmospheres. The experiment showed the Limiting Oxygen Index (LOI — i.e., the minimum O2 level necessary to sustain a flame) could be as low as 12 percent for oxygen-nitrogen atmospheres and even dramatically lower, at 7 percent, for an O2/N2 atmosphere diluted with xenon. FLEX-2 extended the scientific scope of FLEX by examining the burning characteristics of reference fuels for measuring engine efficiencies; the behavior of fuel mixtures with highly disparate volatilities; the interactions of fuel droplets for developing enhanced spray combustion theories; and sooting formation and transport with different fuels.

A flammability experiment performed in the ISS Microgravity Science Glovebox, the Burning and Suppression of Solids experiment utilized ISS nitrogen to vitiate the atmosphere within the glovebox, discovering the skewed nature of the oxygen-flow flammability boundary of materials where the flame blowoff side of the boundary has a much more gradual slope than the steep quenching branch at very low flows. The minimum in the boundary occurs at oxygen levels below limits found in normal gravity flammability screening tests.

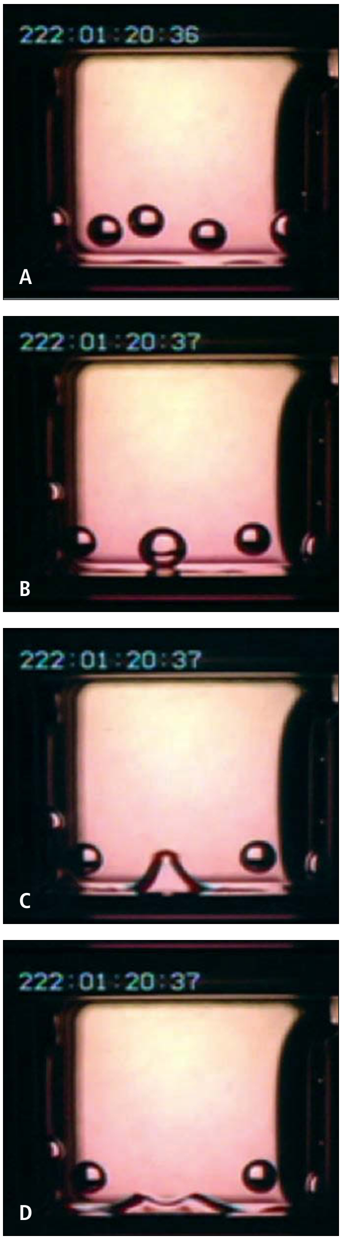
The Supercritical Water Mixture experiment, a precursor to anticipated high pressure combustion research, completed its fourth of six test sequences. This experiment is an international collaboration between NASA and CNES, the French Space Agency, designed to look at precipitation phenomena at near critical conditions.

The Light Microscopy Module or LMM completed the Advanced Colloids Experiment-M1 that seeks a better understanding of product stability using depletion attraction. ACE-M1 was a recipient of one of the “Most Compelling Results from the International Space Station in 2013” award. The LMM also ran ACE-M2, which is presently exploring the roles of gelation and phase separation at the microscopic level in driving the behavior of attractive colloidal systems. The ground-based version of the LMM tested thawed protein crystal samples that had been frozen at -80C. These will be used to grow protein crystals for the MacroMolecular Biophysics experiment and observe them using the LMM on the ISS, where gravitational effects like sedimentation have been reduced by a factor of a million. These samples will be compared with the same samples grown on Earth to confirm models that tell scientists what and how to grow large protein crystals in space, enabling them to determine the protein structure using x-ray diffraction when the crystals are returned to Earth.

The Capillary Flow Experiment-2 kept crew members aboard the ISS busy with 17 operations this year. This experiment contains a suite of hand-held modules with test chambers that vary in geometry. A high-resolution camera captures the capillary motion of the red-dyed silicon oil through these interior corners and gaps inside each test chamber. Drainage tests, passive phase separation tests, and coalescence tests provide data during operations to guide theory development. Results of this research will verify and improve design codes for passive phase separators and fluid management devices.

The Capillary Channel Flow, CCF, experiment was operated in the Microgravity Science Glovebox. This joint effort between teams in the U.S. and Germany investigates capillary flow through an open channel in microgravity under pressure-driven conditions in the inertia flow regime.

Interfacial stability at high flow rates and passive two-phase separation were the focus of operations in 2014. The CCF experiment developed two-phase separation regime maps by sweeping through a large parameter space. Parameters such as liquid flow rate, gas flow rate, and the length of the open channel were identified to influence passive phase separation. ⩓



This sequence of images from the Capillary Channel Flow experiment in the ISS Microgravity Science Glovebox illustrates that phase separation in a wedged-shaped, open channel depends on the bubble size. The small bubbles (a) do not coalesce with the free surface. However, when the small bubbles coalesce with each other (b) a larger bubble forms which is able to coalesce with the free surface and exit the channel (c and d).

Missile technology made headlines

by Darren Hayashi and the Missile Systems Technical Committee

The ***Missile Systems Technical Committee*** *focuses on technologies associated with the design, development, operations, and utilization of strategic and tactical missile systems.*

Missile technology was often at the forefront of world events in 2014, from the destruction of Malaysia Airlines flight 17 over Ukraine by what was most likely an SA-11 surface-to-air missile to Israel's Iron Dome defense system that countered rocket and mortar attacks launched from the Gaza Strip.

Anti-ship missile development remained a priority. Led by the U.S. Defense Advanced Research Projects Agency and Office of Naval Research, the **Long Range Anti-Ship Missile** completed two demonstrations with another planned for December. LRASM leverages Lockheed Martin's Joint Air-to-Surface Standoff Missile-Extended Range but adds a multimode sensor to locate and identify ship targets, an altimeter for low-altitude sea-skimming and a data link for in-flight updates. LRASM is being developed for rapid deployment by the Air Force and Navy.

DARPA

Long Range Anti-Ship Missile.

Norway's Kongsberg tested its **Naval Strike Missile** anti-ship weapon at the Rim of the Pacific naval exercises in July and during a launch from a U.S. Navy littoral combat ship in September. An air-launched version, called the Joint Strike Missile and compatible with the F-35's internal weapons bays, is also in development with Raytheon.

Other surface attack successes include 16 launches of the Lockheed Martin **Direct Attack Guided Rocket** from an AH-64D helicopter at Eglin Air Force Base, Florida. DAGR adds a laser-guidance kit to Hydra 70 rockets for precision engagement of soft or lightly armored targets. DAGRs can be fired in rapid succession at different targets using multiple laser designators.

In air defense, the U.S. Army achieved the first intercept of a cruise missile and unmanned aerial system using Raytheon's **Accelerated Improved Intercept Initiative** missile. AI3 missiles used a semi-active seeker to intercept both targets at low altitude in a high-clutter marine environment. AI3 is part of a mobile, ground-based weapon system designed to acquire, track, engage and defeat unmanned aircraft, cruise missiles, rockets, artillery and mortars.

The U.S. Navy strengthened its ship defenses with its acceptance of the **Rolling Airframe Missile Block 2** in August. Produced by Raytheon in the U.S. and RAMSys of Germany, RAM defends against anti-ship cruise missiles, helicopter and airborne threats, and surface craft. Block 2 introduces a new rocket motor, redesigned control system and evolved radio frequency receiver to increase range and maneuverability.

In ballistic missile defense, the U.S. Missile Defense Agency conducted the first flight of Raytheon's **Standard Missile-3 Block 1B** from the Aegis Ashore system in May. The test confirmed functionality of launching and targeting the land-based SM-3 missile against a simulated target. The first European Aegis Ashore site is to be operational in 2015.

The **Ground-based Midcourse Defense** system conducted a sophisticated BMD test in June. The GMD fire control received targeting data from a U.S. Navy destroyer that detected and tracked a ballistic missile target launched from the western Pacific. The target was destroyed after Army soldiers at Schriever Air Force Base in Colorado remotely launched an interceptor from Vandenberg Air Force Base in California that propelled a second-generation Exoatmospheric Kill Vehicle into space. The EKV maneuvered to identify, intercept and destroy the warhead with direct impact.

Internationally, Rafael's **Iron Dome** system recorded a success rate exceeding 90 percent while intercepting over 500 rockets during the Israel-Gaza conflict. Israel continues deploying a layered defense that includes Iron Dome, David's Sling and Arrow. The latest Arrow 3 interceptor engages ballistic missiles at high altitudes and completed its second flight in January.

Other technology research intends to improve mission adaptability and lower cost. Both the U.S. Air Force Research Laboratory and U.S. Naval Air Systems Command are exploring flexible weapon concepts emphasizing modularity, open architectures and standard interfaces to accommodate new technologies and mission requirements.

Building toward sustainable living in space

by Maria João Durão, Barbara Imhof, Don Barker and Mark Kerr

The ***Space Architecture Technical Committee*** *focuses on the architectural design of the environments where humans will live and work in space, including facilities, habitats and vehicles.*

"Thresholds of Space," a retrospective exhibition of work by David Nixon, one of space architecture's most prominent figures, was launched in Prague, Czech Republic, in late 2013 and is traveling to London in 2015-2016. Spanning a period from 1982 to 2012, Nixon's work reveals the trajectory that space architecture developed as a profession, and "Thresholds of Space" is a milestone in the history of space architecture exhibitions.

With NASA Innovative and Advanced Concept funding, **Water Walls** was launched as a space architecture concept. Led by Astrotecture, the team aims to provide a life-support system that is biologically and chemically passive, based on highly reliable forward osmosis processes. The Water Walls would process urine and wash water, process air to remove carbon dioxide, and grow food using green algae, all while protecting crews from the harmful radiation of space. A system of Water Walls bags, including all the subsystems and their various component bag types, can be installed into a full-featured space habitat.

Another project that promotes sustainable living in space is the **Veggie** Vegetable Production Unit. Orbital Technologies Corp. has been awarded NASA contracts to support the development and flight of this deployable growth unit designed to produce fresh vegetables on the International Space Station. Easily stowable, it consists of a plant cultivation device that provides lighting and nutrient supply for a growing area of 0.17 square meters.

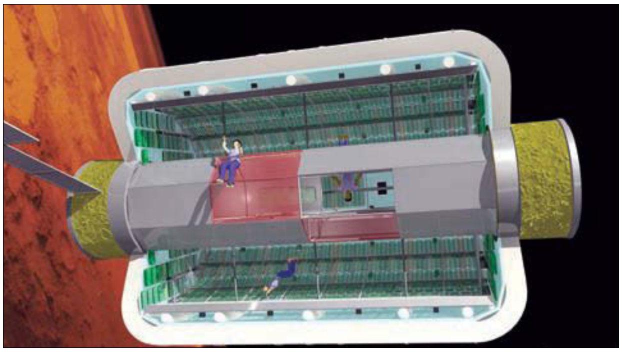
Significant architectural work has been carried out at NASA's Jet Propulsion Laboratory by the **Exploration Systems Concepts Group** of the Mission Systems Concepts Section. The initiative is to develop workstation and rack and standoff designs for deep space habitats. Parts of the design were tested in cooperation with the NASA Desert RATS — Research and Technology Studies — in missions between 2010 and 2012.

In Europe, a **Self-Deployable Habitat for Extreme Environments** is under construction. This three-year project will conclude in 2015. It is being developed under a contract awarded through the European Commission's Seventh Framework Programme-Space, with two space architecture companies (out of seven partners) as main contributors: Liquifer Systems Group of Austria and Space Innovations of the Czech Republic.

Despite not being selected for NASA's Commercial Crew Program, Sierra Nevada continues work on its winged, lifting-body **Dream Chaser** spacecraft, and returns to the age-old problem of size and launch mass. Interior architectural designs surrounding crew systems include innovative seating for four crewmembers and cargo stowage are under development. Integrating human factors with operations such as nominal and emergency ingress and egress poses complex and novel spatial design problems, and a challenge for space architects and designers.

A research challenge was presented to students at Vienna University of Technology with the **MASH project**, which resulted in a concept for a deployable and portable emergency shelter for use on Mars. This academic experience was carried out in one of the few universities that offer studio-based practices and is an example of how central education is for space architecture to be ready for Mars.

Creative thinking and innovative practice in the context of education allows for the renewal of space architecture and industrial design and guarantees the continuity of a field that has been in progressive development for the last 20 years.



François Lévy

Water Walls air revitalization bags inside the perimeter of an inflatable habitat.

University of Tartu

SHEE Consortium, Self-Deployable Habitat for Extreme Environments manufacturing.

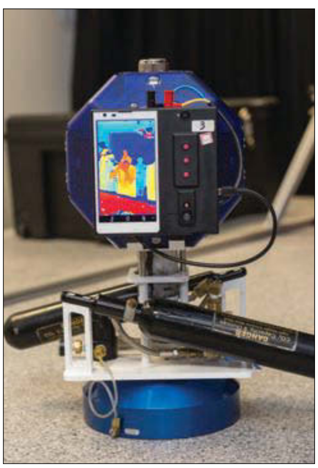
ISS tools, space exploration show robotics progress

by Kate Stambaugh, Gregory P. Scott and David Spangler

*The **Space Automation and Robotics Technical Committee** works to advance the development of these technologies and their applications to space programs.*

Developments in space automation and robotics this year range from experiments in orbit, to rovers on the Moon and Mars, to future missions still in development. The following highlights represent a small fraction of the latest work in this multidisciplinary field.

In July, NASA launched a Project Tango prototype Android smartphone to the International Space Station as an upgrade to the Synchronized Position Hold, Engage, Reorient Experimental Satellites, or SPHERES, which are bowling-ball-sized robotics that operate inside the station. The Tango phone, which was created by Google's Advanced Technology and Projects division, is capable of 3-D mapping and tracking its own position and orientation in real time. The upgraded robots, called **Smart SPHERES**, could perform a variety of activities inside the station, including interior environmental surveys, inventory and mobile camera work.



NASA Ames/Eric James

Smart SPHERES are Synchronized Position Hold, Engage, Reorient Experimental Satellites equipped with Google's Project Tango smartphone.

Robonaut 2, the humanoid robot that has been on board the ISS since 2011, received a pair of legs this year. While the torso uses a humanoid form factor, the legs offer more degrees of freedom than human legs to allow for increased flexibility in Robonaut 2's activities. The legs can operate both internally and externally to the station, although the torso will require upgrades before it can be used externally. Back on Earth, technologies developed for the legs have also been transitioned into NASA's X1 Robotic Exoskeleton, which has applications for strength augmentation and physical therapy in space as well as on the ground.

The Chinese Yutu lunar rover became immobile in January but continued to perform scientific operations.

CNSA/ChinaNews/Ken Kremer/Marco Di Lorenzo

Building on their ISS demonstrations, the team behind NASA's **Robotic Refueling Mission** continues to makes strides in on-orbit fuel transfer. In orbit, the tests have used liquid ethanol, a safe stand-in for normal satellite fuel. This year the ground team performed the Remote Robotic Oxidizer Transfer Test, which used the hazardous and corrosive oxidizer of real propellant. These ground tests included the transfer of nitrogen tetroxide at a confined test facility at NASA's Kennedy Space Center in Florida while being controlled by robot operators at the Goddard Space Flight Center in Maryland.

For geosynchronous orbit, DARPA continues to push developments in **orbital robotics** for improved satellite servicing. The servicing and proximity operations technologies needed for the program have the potential to extend the lives and lower the cost of space missions. DARPA is emphasizing three servicing capabilities: high-resolution cooperative inspection, including difficult-to-reach locations; orbit adjustment assistance, to add flexibility to geosynchronous fleet operations; and mechanical assistance with deployment anomalies.

On Aug. 5, NASA's **Curiosity rover** marked its second anniversary on Mars. The rover continues to traverse the surface and search for signs of conditions that might support life, and it has found more evidence of past water on Mars near Gale Crater. The rover continues to study the surface and has reached Mount Sharp, its destination since landing.

This year marks the 10th anniversary of the Mars Exploration Rover mission. With an odometer reading over 25 miles, the **Opportunity rover** has broken the record for the longest distance traveled on an extraterrestrial surface. The Soviet Union's Lunokhod 2 lunar rover previously held the record at 24.2 miles. The Opportunity rover continues to perform science on the surface of Mars today.

A new player has entered the scene of planetary surface robotics. In December 2013, the Chinese Chang'e 3 spacecraft landed on the Moon and released a small rover called **Yutu**, or "Jade Rabbit." The rover drove about 110 meters before becoming immobile in late January, but continued to perform science operations while stationary. The science payload on board Yutu included a ground-penetrating radar, two spectrometers and several cameras. The mission lasted about six months and was the first soft landing and roving mission to the Moon since 1976.

Small steps toward space commerce

by Anita Gale, Ron Kohl and Mike Snyder

*The **Space Colonization Technical Committee** promotes the development of advanced concepts, science, and technology to enable and enhance permanent human presence in space.*

This year saw continued efforts toward expanding human economy throughout cislunar space. While there is still no clear development or unified planning of integrated infrastructure components to enable future space settlement, small steps are being made toward that big goal.

The **International Space Station** continues to be the primary focus of commercialization. Cargo deliveries in the past year included two flights by the SpaceX Dragon and two by the Orbital Sciences Cygnus vehicle under the Commercial Resupply Services contracts. A third Cygnus resupply mission failed in October when the Antares launcher exploded shortly after liftoff. NASA has issued a preliminary request for proposals for continuation of commercial cargo deliveries through CRS2.

In September, NASA announced that it had awarded **Commercial Crew** contracts to SpaceX and Boeing for the next phase of vehicle development through initial flights starting in 2017. SpaceX is offering a crewed version of the Dragon cargo vehicle and Boeing is developing its CST-100 capsule. Sierra Nevada, which offered its Dream Chaser winged vehicle, was not selected for the program, but the company intends to continue development of the vehicle.

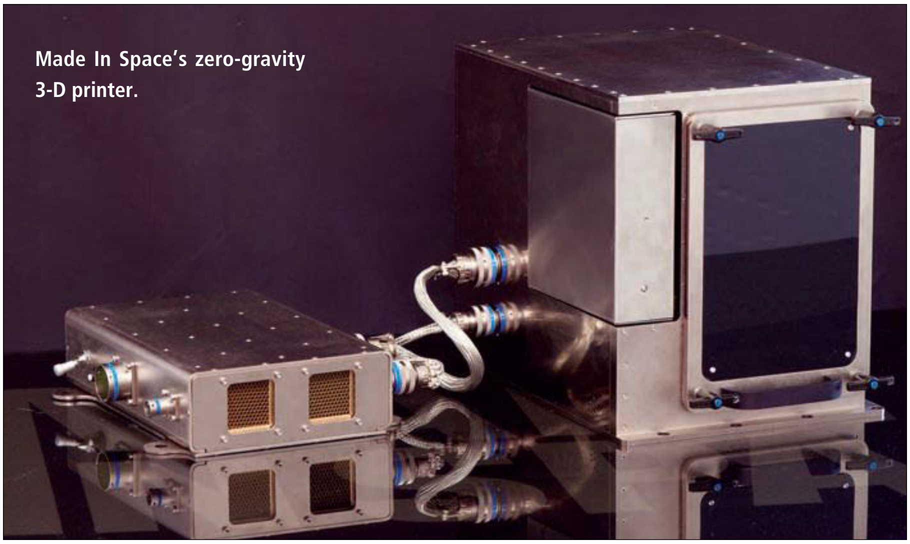
Management of ISS as a **National Laboratory** by the Center for the Advancement of Science in Space, or CASIS, is yielding impressive research results. For example, the capability to crystallize proteins in weightlessness reveals previously unknown protein structural features, enabling development of new drugs, at least one of which is now in testing. A rodent research facility will initially enable studies for 30 to 60 days, and eventually 180 days with either mice or rats. Research from this facility is expected to include studies of disease, testing of drugs, and better understanding of bone and muscle loss in space. The Hyperspectral Imager for the Coastal Ocean has demonstrated clear imaging of algae blooms, which aids understanding of environmental effects on water quality. Long-term experience in space enabled by CASIS can lead to the products that will eventually show how to make profits by manufacturing in space, a prerequisite to large-scale habitation.

Direct progress toward **space manufacturing** is being accomplished by Made In Space Inc. with the creation of a 3-D printer that arrived on ISS in September. The company recognizes this is just a first step, with plans being developed for a permanent Additive Manufacturing Facility on ISS.

Another possible path toward space commerce is suggested by a DARPA request for information on development of **robotic servicers** for spacecraft inspection and relocation in and near geosynchronous Earth orbit. The agency is trying to learn whether commercial on-orbit satellite servicing could become financially self-sustaining.

Interest in **space solar power** continues to grow. The U.S. Department of Energy's website, for example, featured a "Space Week" with the message that "solar power directly from space may arrive sooner than you think." Conferences brought experts together several times during the year, with strong interest in Japan and China. A book by John Mankins, "The Case for Space Solar Power," suggests a roadmap for operational solar power satellites within 20 years, driven by a business model and recognizing that the timeline will be flexible.

Also newly published is "Space Elevators: An Assessment of the Technological Feasibility and the Way Forward," resulting from a study by the International Academy of Astronautics. The goal is more affordable access to space. The book acknowledges that the biggest challenge is a producible material with "strength, length and perfection needed to enable a 100,000km long tether. Almost all other issues … have either been resolved in space before or are close to being space ready today."



Made In Space's zero-gravity 3-D printer.

Made In Space

A year of space operations milestones

by Michael Squire

*The **Space Operations and Support Technical Committee** focuses on operations and relevant technology developments for manned and unmanned missions in Earth orbital and planetary operations.*

On Jan. 20, controllers in Darmstadt, Germany, received a signal from the **Rosetta** spacecraft — a "yawn" that told European Space Agency controllers that Rosetta had awoken after a 957-day hibernation and was ready for the final leg of a journey to the comet Churyumov-Gerasimenko. Rosetta arrived Aug. 6 and is now safely in orbit around the comet, which the spacecraft will accompany as it passes near the sun next year. On Nov. 12, Rosetta deployed the Philae lander, which became the first spacecraft to soft-land on a comet.

Another comet, **Siding Spring**, created a stir in October when it approached within 135,000 kilometers of Mars. Since the comet's trail of particles posed a debris hazard, the various spacecraft orbiting Mars were maneuvered so they could use the planet as a shield. Two of those Mars orbiters had just arrived in September. One was the Mars Atmosphere and Volatile Evolution spacecraft — NASA's mission to explore the planet's upper atmosphere, ionosphere, and interactions with the sun and solar wind. Arriving three days after MAVEN was India's first interplanetary mission, the Mars Orbiter Mission.

Down on the surface, the exploration rover **Opportunity** marked its 10th anniversary on Mars in January. Sporting solar panels scrubbed clean by Martian winds, which allowed more energy intake from the sun, Opportunity broke the off-Earth driving distance record when it passed the 40-kilometer mark on July 27. This broke the record held since 1973 by the Soviet Lunokhod 2, prompting the Opportunity team to name a nearby crater Lunokhod 2 as a salute. On the opposite side of the planet, the Mars science laboratory rover **Curiosity** continued its mission as well. Due to accumulating damage to Curiosity's wheels, controllers have had to modify its driving routine to find a path with the smoothest terrain possible.

European Space Agency

Rosetta Mission Control at the European Space Operations Centre.

A milestone was passed on a far side of the solar system when the **New Horizons** spacecraft crossed Neptune's orbit on its way to next year's rendezvous with Pluto. This crossing occurred on the 25th anniversary of Voyager 2's encounter with Neptune, the only previous visit to the planet. New Horizon was launched in January 2006.

CubeSats just released from the ISS.

NASA

Closer to home, NASA's Lunar Atmosphere and Dust Environment Explorer, known as **LADEE**, ended its mission as planned on April 17 with an impact on the lunar surface. Controllers worked quickly to gather and download unique low-altitude science data as the spacecraft descended to just above the surface prior to the final collision. The Chinese had a softer landing on the Moon with their Chang'e 3 spacecraft on Dec. 2, 2013, which delivered the first Chinese lunar rover, Yutu. Yutu drove around on the Moon's surface gathering data until the end of January when malfunctions brought it to a halt.

In Earth orbit, Planet Labs' flock of 28 Earth-imaging **CubeSats**, which the company calls "doves," was deployed from the International Space Station in February. Lithuania's first two satellites were also CubeSats and also deployed from ISS. Peru, Iraq and Uruguay all had CubeSats as their countries' first satellites this year. Bolivia's first was a more traditional-sized communications satellite.

Commercial resupply of ISS continued to grow this year with the first two resupply missions by Orbital Sciences' Cygnus spacecraft. Unfortunately, the third Cygnus mission was lost in October with the failure of the Antares launch vehicle seconds after liftoff. Nevertheless, by the end of the year, Cygnus and SpaceX's Dragon will have transported approximately 20 percent of the total cargo delivered to ISS in 2014. ISS also had its first commander who was neither American nor Russian this year when Koichi Wakata became the inaugural Japanese ISS expedition commander.

Crowd-funding, tool tests to clear way for space resource collection

by Kurt Sacksteder

*The **Space Resources Technical Committee** advocates affordable, sustainable human space exploration using non-terrestrial natural resources to supply propulsion, power, life-support consumables and manufacturing materials.*

Along with lunar, planetary and asteroid scientists, space resource advocates are conceiving new exploration approaches and advanced technology concepts under a paradigm in which scientific advancement helps to identify resources, and resources enable scientific exploration.

NASA's **Life in the Atacama**, or LITA, team is making plans to return to the Chilean desert in 2015 to conduct more tests of sample-collection technologies. In 2013, Honeybee Robotics deployed a fully robotic 1-meter-long drill in the Atacama on a Carnegie Mellon University-designed rover called Zoë. The 10-kilogram LITA drill captured samples from target depths and delivered them to a carousel for analysis by instruments that included a Raman spectrometer. In 2014, Honeybee also tested the LITA drill in the Mojave Desert. LITA is part of NASA's Astrobiology Science and Technology for Exploring Planets program.

Deltion Innovations Ltd., a maker of **space mining** equipment, moved from a location in Sudbury, Ontario, to a newly acquired 28,000-square-foot facility located approximately 30 kilometers away in Capreol, Ontario. This move will allow the company to expand its labor force as the need arises over the next couple of years.

Deltion and the Colorado School of Mines are planning the May 2015 Planetary and Terrestrial Mining Sciences Symposium/Space Resources Roundtable in conjunction with the Canadian Institute of Mining Annual Convention, with the intention of promoting space resource utilization to the terrestrial mining industry. The institute has over 14,000 members from all sectors of the mining and petroleum industries.

Researchers from the Center for Space Exploration Technologies Research at the University of Texas at El Paso investigated extracting water from **lunar polar regolith** using a concept, proposed by ExoTerra Resource, involving beaming power from solar concentrators to regolith in shadowed craters. The researchers developed regolith heat-transfer models and validated their modeling using laser beams to simulate concentrated solar power.

Planetary Resources Inc.'s demonstration satellite, **Arkyd 3,** was among the payloads destroyed when an Antares rocket failed in October. The plan was to deploy the satellite from the International Space Station's Japanese airlock to test avionics and failure points for PRI's Kickstarter-funded Arkyd telescope, which the company describes as the "first publicly accessible space telescope." PRI said on its website that it will "live to fly another day" and continue work on its next test satellite, Arkyd 6. PRI also signed a Space Act Agreement with NASA to create a crowdsourced algorithm challenge called Asteroid Data Hunters, and partnered with Zooniverse to launch Asteroid Zoo, a web-based asteroid detection challenge.

At NASA's Glenn Research Center, the **Mars Atmospheric Chemistry System** was improved to add low-temperature capability, complementing the high-fidelity simulation of Mars atmosphere composition, dust, and pressure environment for in situ resource utilization component testing. The Glenn VF-13 facility commissioned a removable cold wall, in addition to the cryogenic soil bin, making it the largest available dirty thermal-vacuum facility. This year, hardware concepts and instrumentation for subsurface soil extraction and volatile retention were tested in lunar thermal/vacuum environment.

Members of the Space Resources Technical Committee engaged in outreach and unfunded, interest-driven technology development. Matthew Cross, a Ph.D. student at the University of Western Ontario, led preschoolers to demonstrate lunar impact cratering and lunar resource mining using flour as regolith, golf balls as meteors and marshmallows as buried resources. Doug Plata, author of the Cis-lunar One plan for sustainable space development, performed a demonstration of hydrogen-oxygen propellant production from a soil/water mixture based on moisture ratios measured by LCROSS — the Lunar Crater Observation and Sensing Satellite — plus microwave water extraction and electrolysis reactant separations. Representing NASA Glenn, I presented concepts for propellant production using Mars atmosphere and water resources to a statewide Ohio STEM program emphasizing innovation and entrepreneurism among high school students.

Committee members participated in in-situ-resource-utilization-related updates to the 2011 NASA Office of Chief Technologist Technology Roadmaps. The roadmaps help organize the broad spectrum of technology development investment options to enable and enhance more affordable human and robotic exploration of space.

Carnegie Mellon's Zoë rover.

Carnegie Mellon University

Honeybee Robotics

LITA drills in the Atacama Desert.

Large and small systems make progress

by Samantha Infeld

The ***Space Systems Technical Committee*** *fosters the development, application, and operation of space systems and addresses emerging issues in the area.*

Space system launches and announcements this year were increasingly about small and commercial systems, including a constellation of CubeSats. But there were also major tests completed of NASA's Orion spacecraft, part of the Space Launch System for human exploration beyond Earth orbit and backup transportation to the International Space Station.

Coming into 2014 many were following the progress of the Chinese **Yutu rover** after its landing on the moon in December 2013, when just before it entered its second lunar night on Jan. 25 it failed to fold its solar panel down properly after hitting a rock. This configuration left its sensitive electronics exposed to the cold and it was thought the rover would not wake up again. But the rover came back online in February and sent back data for months as its instruments continued to degrade while Yutu managed to survive successive lunar nights.

The LightSail project aims to use the pressure of sunlight to propel a spacecraft.

The Planetary Society

In February and March, **Planet Labs'** Flock 1 of 28 CubeSats, the world's largest constellation of Earth-imaging satellites, launched from the ISS along with five other CubeSats in a record-breaking deployment. With subsequent launches, Planet Labs' now has 71 CubeSats in orbit and the company is approaching the capability to image the entire Earth, every day.

After months of testing and critical design reviews in 2014, NASA selected two companies, Boeing and SpaceX, for its **Commercial Crew Program** to provide transportation to the ISS and low-Earth orbit. Boeing offered the CST-100 crew capsule and SpaceX proposed the Dragon v2, a crewed version of the Dragon cargo vehicle that has made several resupply missions to the ISS.

The parachute system for NASA's **Orion** deep-space vehicle was tested over Arizona in June following tests in January, and the largest heat shield ever constructed was installed on the Orion crew module at Kennedy Space Center in Florida. Then in August, ocean testing off California was completed in preparation for the first space flight test, scheduled for December. These engineering feats were accomplished in cooperation with several large and small companies, including prime contractor Lockheed Martin and Analytical Mechanics Associates.

In June, NASA selected proposals for six-month studies to mature system concepts and assess the feasibility of potential commercial partnerships to support the agency's **Asteroid Redirect Mission**. Notably for space systems, Airborne Systems, Jacobs, Altius Space Machines and Space Systems/Loral are carrying out the asteroid capture systems studies, while The Planetary Society, Planetary Resources, Applied Physics Laboratory, Honeybee Robotics and Deep Space Industries are developing secondary payload possibilities.

In August, The Planetary Society announced 2015 and 2016 launch dates for its **LightSail-1** spacecraft, a CubeSat to be launched by SpaceX. Also that month, the European Space Agency's Rosetta mission achieved a milestone by becoming the first spacecraft to rendezvous with a comet, 67P/Churyumov-Gerasimenko. In November, Rosetta deployed the Philae robotic lander, which settled on the comet.

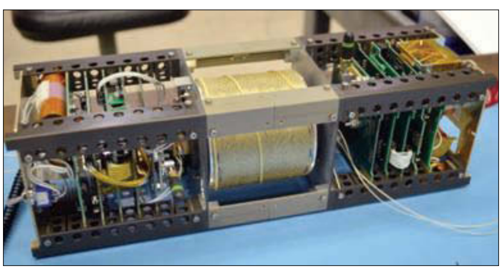
Tether modules launched, more spacecraft planned

Sven G. Bilén

*The **Space Tethers Technical Committee** focuses on the development and use of tether-based technology for space systems.*

The space tethers community has launched several tether modules and is preparing several spacecraft for upcoming launches. New technologies and mission concepts are being explored.

Two **Terminator Tape** deorbiting modules developed by Tethers Unlimited Inc. are scheduled to begin operating in 2015 to deorbit their host CubeSats, which will have completed their missions. Two larger Terminator Tape modules, sized for small microsatellites, were delivered to the Air Force Research Laboratory's University Nanosatellite Program for use on two student-built satellites to be launched in 2016. Tethers Unlimited has also been selected to supply the end-of-life deorbit solution for Surrey Satellite US's Orbital Test Bed mission slated for launch in 2015.



NRL

The Naval Research Laboratory's TEPCE 3U CubeSat.

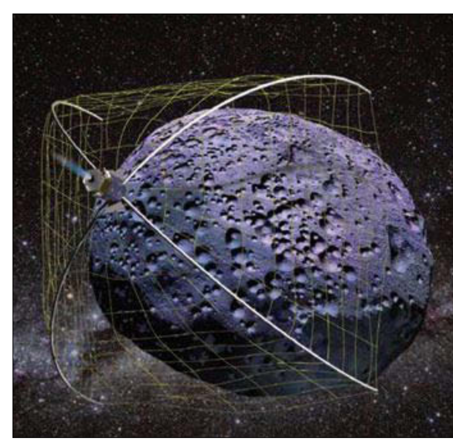
The Naval Research Laboratory is preparing for launch of a **Tether Electrodynamics Propulsion CubeSat Experiment** spacecraft through the U.S. Air Force's Satellite Test Program. With body-mounted solar cells and tungsten filament cathodes, TEPCE will demonstrate electrodynamic propulsion in low Earth orbit. TEPCE will be launched into an as-yet-unspecified orbit that will allow it to operate for many years providing extensive data on its electrodynamic propulsion system.

Star Technology and Research and subcontractors Tether Applications, the Naval Research Laboratory, and Boeing completed a two-year NASA technology-maturation contract for their **ElectroDynamic Delivery Express** spacecraft. EDDE is being designed for propellantless orbit changes in low Earth orbit and can distribute microsat and nanosat payloads to widely-spaced multiple orbits from a single launch vehicle. Weighing 24 kilograms, Mini-EDDE is packaged into a 12U CubeSat format and has 1.6-kilowatt solar arrays powering a 1.8-kilometer-long ribbon conductor.

The **Propulsion Using Electrodynamics PROPEL** team — Tethers Unlimited, NASA Marshall, Northrop Grumman, Millennium Space Systems, Penn State and the University of Michigan — developed several implementation options for PROPEL to demonstrate its versatility: A comprehensive mission design with a mission duration of six months; a space demonstration mission concept design with configuration of a pair of tethered satellites, one of which would be the Japanese H-2 Transfer Vehicle; or a system based on an Evolved Expendable Launch Vehicle Secondary Payload Adaptor.

As part of NASA's Innovative Advanced Concepts program, NASA's Jet Propulsion Laboratory and UCLA are working on a concept called **Comet Hitchhiker** to hitch a ride on comets to tour around the solar system. A tethered spacecraft would accelerate or decelerate itself without fuel by harvesting kinetic energy from a target body.

Under a separate grant from the same program, Tethers Unlimited has begun work on a concept called **WRANGLER** for Weightless Rendezvous And Net Grapple to Limit Excess Rotation. A momentum-exchange tether technique would be used to enable a small, lightweight nanosatellite to capture and de-spin a massive asteroid to reduce risk and costs for NASA's Asteroid Redirect Mission as well as future asteroid-mining operations. A system called **SPIDER**, for Sensing and Positioning on Inclines and Deep Environments with Retrieval, is also being developed for tether-facilitated sampling of asteroids via a deployment-and-retraction system. On another NIAC grant, the University of Washington and Tethers Unlimited are exploring concepts for using tethers to deliver a high-velocity impact sampler to small planetary bodies such as Ceres and then retrieve the resulting sub-surface samples.



Tethers Unlimited

The WRANGLER system would use a thin, lightweight tether to enable a 10-kilogram nanosat to de-spin a 1-million-kilogram asteroid.

The University of Michigan continued to develop the **Miniature Tether Electrodynamics Experiment**, MiTEE, CubeSat demonstration mission, which will demonstrate 10-meter electrodynamic tethers for drag make-up and boosting of femtosat-sized spacecraft using less than 1 watt. A high-altitude balloon flight demonstrated MiTEE's communication architecture.

Saber Astronautics completed the second round of testing in Houston for its **DragEn** tether deployment system as part of NASA's Flight Opportunities Program. Having already demonstrated deployment and rollout of the tether in zero gravity, testing focused on various friction-based deceleration strategies.

Active year for government, commercial launches

by Jim Knauf and the Space Transportation Technical Committee

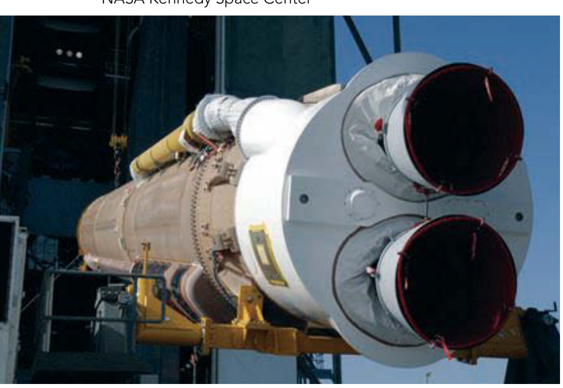
*The **Space Transportation Technical Committee** works to foster continuous improvements to civil, commercial and military launch vehicles.*

The year saw a brisk worldwide launch pace, milestones for new government and commercial launchers, a U.S. commercial crew capability decision and advances on new launch sites.

NASA completed a critical design review for the **Space Launch System** heavy-lift rocket to carry humans beyond Earth orbit and committed to a $7 billion development program with initial flight scheduled in 2018. The agency's Stennis Space Center began testing the modified space shuttle engine that will power the vehicle's core stage.

In September, NASA awarded contracts to Boeing and SpaceX for its **Commercial Crew Program** to develop a capability to deliver astronauts to the International Space Station. Boeing is developing the CST-100 capsule to be launched on Atlas 5 rockets, and SpaceX is producing the Dragon v2 capsule for its own Falcon 9 launcher.

NASA Kennedy Space Center



An Atlas 5 with RD-180 rocket engines built by the Russian company NPO Energomash.

Orbital Sciences flew two ISS resupply missions with its **Antares** launcher and **Cygnus** cargo spacecraft, and considered replacement of the booster's modified Russian engines. A third mission in October failed when the Antares launcher exploded shortly after liftoff.

SpaceX sustained an active **Falcon 9** launch pace with three ISS cargo and four commercial satellite missions, and partially demonstrated a first stage soft ocean landing. The company completed vertical landing demonstrations with its Grasshopper single-engine test vehicle. A subsequent three-engine vehicle was lost, but high-altitude demonstration tests are planned for New Mexico's Spaceport America.

The U.S. Air Force's Space and Missile Systems Center and NASA's Launch Services Program continued intensive efforts to certify Falcon 9 for government missions. SMC conducted engineering integration for two low-risk Falcon 9 flights and held the first Evolved Expendable Launch Vehicle competitive acquisition since 2006.

United Launch Alliance anticipated 13 **Atlas** and **Delta 4** launches, including a Delta 4 Heavy with an uncrewed test of NASA's Orion spacecraft, and one Delta 2 launch. Geopolitical events, including Western sanctions on Russia over events in Ukraine, highlighted U.S. dependence on Russian RD-180 engines for Atlas. There was no disruption to engine deliveries, but the U.S. contemplated a new domestic hydrocarbon engine. There were similar concerns about U.S. dependence on the Russian Soyuz for crew transportation to ISS.

Manufacturing of Space Launch System flight hardware is underway at the Michoud Assembly Facility in Louisiana.

NASA

NASA leased Apollo/Shuttle Launch Complex 39A at Kennedy Space Center to SpaceX for commercial use. Texas and SpaceX announced plans for a commercial launch facility in that state. Russia continued construction of an eastern launch site at Vostochny while China neared completion of the Wenchang Launch Center.

Stratolaunch chose Aerojet Rocketdyne RL10 engines for stage three of its **Thunderbolt** air-launched vehicles in development by Orbital Sciences. Construction of the system's carrier aircraft, the largest in the world, was 50 percent complete. Scaled Composites is building the aircraft in Mojave, California. The system is to launch Delta 2-class satellites beginning in 2018.

Russia flew a suborbital first test of the **Angara** rocket, its first entirely new post-Soviet Union launcher. Eight Soyuz cargo and ISS crew missions, four of each, launched to the station from Baikonur, Russia. **Proton** and **Rockot** launches resumed with four and two flights, respectively. In May, Proton experienced another in a string of failures in recent years, putting the remaining launch schedule in doubt. This and a Russian-built Soyuz that put two Galileo navigation satellites into incorrect orbits from Europe's spaceport in Kourou, French Guiana, has marred Russia's historic launch success record. A restructuring of the Russian space industry is underway.

Sea Launch resumed operations with a **Zenit 3SL** launch but temporarily mothballed its maritime launch platform and cut staff to address a launch gap through 2015.

The Kourou launch site flew four Arianespace Soyuz, two **Vega** rockets and five **Ariane 5s**, including the fifth and final Automated Transfer Vehicle to the ISS.

India had three launches and a planned fourth-quarter suborbital test of the new **Geosynchronous Launch Vehicle Mk.3** with two large solid boosters, a liquid core second stage and a cryogenic third stage. Japan launched four H-2As. China launched five Long March variants.

Virgin Galactic's commercial suborbital **SpaceShipTwo** broke apart during a test flight in October, killing one pilot and injuring the other. An investigation is underway.

DARPA awarded study contracts for a reusable suborbital space plane dubbed **XS-1**.

Missile defense systems score hits

by James D. Walker

*The **Weapon System Effectiveness Technical Committee** advances the science and technology of predicting, measuring, evaluating, and improving the lethality of weapon systems.*

The year saw extensive use of one of the fielded strategic defense and missile intercept systems: Israel's **Iron Dome**. During the conflict with Gaza, Israel reported 735 rocket interceptions and 70 misses, according to Aviation Week — about a 90 percent intercept rate. Iron Dome has a man in the loop to decide whether to launch an interceptor. Thus, roughly 800 times the decision was made to launch an anti-missile missile against the reported 4,594 rockets and mortars fired from the Gaza Strip.

There was one missile intercept test in the U.S. this year. The Missile Defense Agency and other Defense Department components completed an integrated exercise of the **Ground-based Midcourse Defense**, or GMD, element of the Ballistic Missile Defense System on June 22. Flight Test Ground-Based Interceptor 06b began with the launch of a threat-representative intermediate-range ballistic missile target from the U.S. Army's Reagan Test Site on Kwajalein Atoll in the Pacific Ocean. Six minutes later a long-range ground-based interceptor was launched from Vandenberg Air Force Base, California.

A U.S. Navy vessel using the Aegis Weapon System AN/SPY-1 radar detected and tracked the target. The Sea-Based X-Band radar also tracked the target. Both systems relayed information to the GMD fire-control system to assist in the target engagement and to collect test data.

The interceptor rocket had three stages, and placed the kinetic kill vehicle in the target missile's projected trajectory in space. The kill vehicle maneuvered into the path of the target, performed discrimination on various objects traveling with the warhead and intercepted the threat warhead with a "hit to kill," relying solely on a direct collision between the interceptor and the target to destroy the warhead. At the closing velocities involved — in the kilometers per second regime — explosives provide little additional energy above what is provided by the kinetic energy of the vehicles. This was the first intercept using the new second-generation **Exoatmospheric Kill Vehicle**. The intercept occurred over the Pacific Ocean.

The test brought to 65 the number of successful hit-to-kill intercepts in 81 attempts since 2001 for all aspects of the Ballistic Missile Defense System. The GMD element of the system has completed four intercepts using the operationally configured interceptor since 2006. Operational ground-based interceptors are currently deployed at Fort Greely, Alaska, and Vandenberg Air Force Base to provide protection against a limited long-range ballistic missile attack.

This year saw the cancellation of a major ground vehicle program, the Army's Ground Combat Vehicle. With previous years' cancellations of other major ground systems, such as the Marines' Expeditionary Fighting Vehicle and the Army's Future Combat Systems, it is clear that ground vehicle design needs close attention. There have been major efforts to address these problems, including DARPA's Adaptive Vehicle Make program, which wrapped up this year. The goal was to reduce the time from concept to rolling vehicle by a factor of five. The program aimed to develop extensive tools to allow vehicle designers to perform analysis by automating the entire computational pipeline involved in areas such as ballistic armor and blast analysis, and to automate much of the manufacturing and procurement process. Such efforts are required to cut long development times, which are a major threat to weapon system procurement because they lead to requirement creep, cost growth and component obsolescence.

A missile interceptor blasts off from Vandenberg Air Force Base, California.

Missile Defense Agency

Out of the

25 Years Ago, December 1989

Dec. 5 Iraq launches a three-stage rocket said to be capable of orbiting a satellite. NASA, Astronautics and Aeronautics, 1986-90, p. 239.

Dec. 29 The prototype of the McDonnell MD-530N tail-rotorless helicopter makes its first flight. Flight International, Jan. 10-16, 1990, p. 24.

Dec. 31 The first commercial Titan is launched from Cape Canaveral and orbits the British Skynet 4A military and the Japanese JC Sat 2 satellites. Flight International, Jan.10-16, 1990, p. 13.

50 Years Ago, December 1964

Dec. 1 The first full-power static firing of the Saturn-4B's liquid oxygen/liquid hydrogen rocket stage of five J-2 engines is made. Each J-2 delivers 200,000 pounds of thrust for a total thrust of a million pounds. The engines operated normally for 10 seconds at the Douglas Missile and Space Systems Division at Sacramento, Calif. Missiles & Rockets, Dec. 7, 1964, p. 9.

Dec. 1 The first sounding rocket launched by a Latin American country under a cooperative agreement with NASA is made when a U.S.-developed solid-propellant Nike-Cajun is launched from the Chamical range in Argentina. Argentina built the scientific payload and Argentine technicians and engineers conducted the launch after training from NASA. The payload consists of wave propagation, electron temperature, and ion density experiment scientific equipment for studying the ionosphere. The project is administered by the Argentine National Commission of Space Research and NASA. NASA Release 64-304.

Dec. 1 The Houston Colt .45s baseball team changed its name to the Houston Astros, reflecting the fame of the city as the U.S. space capital with the establishment of NASA's Manned Spacecraft Center in 1963. The center was later renamed the Lyndon B. Johnson Space Center, or simply the Johnson Space Center. Aviation Week, Dec. 7, 1964, p. 15.

Dec. 8 It is reported that a team of Canadian scientists from McGill University of Quebec conducted Project Harp (High Altitude Research Program), a series of experiments using a 250-ton, 16-inch naval gun to launch scientific rockets to altitudes of almost 100 miles for the purpose of gathering data on the ionosphere's influence on radio communications. Gerald Bull, who conceived Project Harp, also believes the combination of gun and rocket could be used to orbit light, 100-pound satellites in low-Earth orbits. More than 80 shots are fired in Project Harp, most of which are successful. London Daily Telegraph, Dec. 8,1964, p. 14.

Dec. 8 The first airplane landing made entirely by a computer is carried out by a United Air Lines Caravelle jet at Dulles International Airport, near Washington, D.C. The computer constantly determines the correct altitude, rate of descent and speed in making the landing, without any directions from the pilot. Washington Post, Dec. 9, 1964.

Dec. 8 Retired U.S. Army Maj. Gen. Benjamin D. Foulois, America's first military pilot, is honored for his achievements in aviation at a dinner on his 85th birthday. As a captain in 1916 he was given command of the first U.S. air tactical unit, the 1st Aero Squadron. By 1931 he became chief of the Army Air Corps. In 1964 he was presented with a special Medal of Recognition for his more than 50 years of dedication and service to aviation in a ceremony at the Pentagon. New York Times, Dec. 11, 1964, p. 34.

Dec. 8 NASA conducts a test of the launch escape system of the Apollo spacecraft by means of the solid-propellant Little Joe 2 test vehicle at the White Sands Proving Ground, N.M. Flight International, Dec. 17, 1964, p. 1958.

Dec. 10 The Titan 3-A makes its first successful test flight in a launch from Cape Kennedy, Fla. During its first orbit, the vehicle's 5,250-pound Transtage (third stage with multiple start-stop-restart capability) enables the stage to make a 360-degree somersault to align the platform's inertial guidance system gyroscopes, while at the end of the orbit a 3,375-pound dummy satellite is placed into a separate orbit. New York Times, Dec. 11, 1964, p. 20; Aviation Week, Dec. 14, 1964, p. 27.

Dec. 11 The Aerobee 350, the most sophisticated and final member of the Aerobee family of liquid-propellant sounding rockets, is launched for the first time at Wallops Island, Va., and attains an altitude of 6,600 feet. NASA Report, "Aerobee 350" file, NASM.

Dec. 11 The Atlas-Centaur 4 (AC-4) is launched with a 2,100-pound Surveyor spacecraft mass model in an important test flight toward the first

Past

An Aerospace Chronology
by **Frank H. Winter**
and **Robert van der Linden**

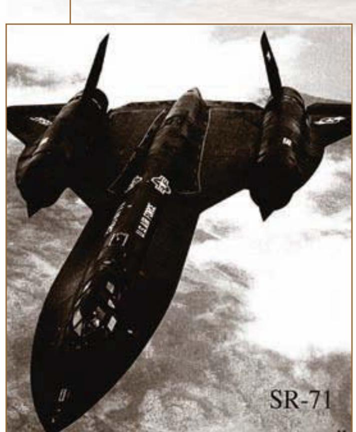
lunar soft landing. Surveyors are sent to the moon to gather critical data on the surface prior to the Apollo manned lunar landings. The AC-4 mission is thus a development flight for the Centaur high-energy upper stage. Aviation Week, Dec. 21, 1964, p. 24.

Dec. 15 The San Marco 1 Italian-designed scientific satellite is launched by a NASA-trained Italian crew by a four-stage, all-solid-propellant Scout rocket at NASA's Wallops Island, Va., facility. This also marks the first time a foreign country designs, builds and launches a satellite as part of NASA's international program. The 254-pound San Marco is to measure air density and radio transmission characteristics in the ionosphere. Aviation Week, Dec. 21, 1964, p. 16; Flight International, Dec. 24, 1964, p. 1100.

Dec. 21 Explorer 26, also known as the Energetic Particles Explorer D, is launched by a Delta rocket from Cape Kennedy, Fla., into an unusual egg-shaped orbit. This allows the windmill-shaped satellite to gather data on how high energy radiation particles are injected, trapped and eventually lost in the Van Allen radiation belts, data needed for the upcoming Project Apollo flights. Washington Post, Dec. 22, 1964; Aviation Week, Dec. 14,1964, p. 55.

Dec. 21 The General Dynamics F-111 Aardvark tactical strike aircraft makes its first flight at Carswell Air Force Base, Fort Worth, Texas, although there is a minor malfunction with the wing trailing edge flap brake lock, thereby shortening a flight that is considered 90 percent successful. Aviation Week, Dec. 28, 1964, p. 18.

Dec. 22 The Air Force's Lockheed SR-71 Blackbird advanced, long-range Mach 3+ strategic reconnaissance plane makes its first flight at Palmdale Air Force Base, Calif., and reaches an altitude of 45,000 feet at 1,000 mph. Powered by a pair of Pratt & Whitney J-58 jet engines with a maximum thrust of 34,000 pounds, the Blackbird eventually flies to more than 2,000 mph and above 80,000 feet. New York Times, Dec. 23, 1964, p. 1.



75 Years Ago, December 1939

Dec. 2 The Army Air Corps is authorized to begin the development of a four-engined bomber with a 2,000-mile range. This will lead to the Boeing B-29 Superfortress. Aeronautics and Astronautics 1915-60, p. 39.

Dec. 20 The Canadian Minister of Defense announces the selection of Squadron 110 of Toronto as the first Royal Canadian Air Force unit to be sent overseas. Flight, Dec. 28, 1939, p. 530.

Dec. 21 A Savoia-Marchetti S.M.83, powered by three 750-h.p. Alfa-Romeo 126 R.C. 34 engines, leaves Rome for the start of the first regular night mail and passenger service between Rome and Rio de Janeiro, a distance of 6,000 miles. The Aeroplane, Jan. 12, 1940, p. 56.

Dec. 23 The Japanese biplane Yamato leaves Tokyo on a goodwill flight to Italy with greetings to Benito Mussolini in his capacity as prime minister and minister of air. The plane lands in Rome on Dec. 31. The Aeroplane, Jan. 12, 1940, p. 58; Interavia, Dec. 27, 1939, p. 18.

Dec. 26 The first Royal Australian Air Force squadron designated for action against Germany arrives in England and is to use Short Sunderland flying boats. The Aeroplane, Jan. 5, 1940, p. 15.

Dec. 30 A Soviet Ilyushin TsKB-55 prototype makes its first flight with famed test pilot Vladimir Kokkinaki at the controls. Heavily armed and armored, the TsKB-55 is designated the Il-2 when it enters service and becomes famous as a ground attack aircraft during World War II. Yefim Gordon et al. OKB Ilyushin: A History of the Design Bureau and its Aircraft, pp. 15-16.

And During December 1939

— Timm Aircraft, pioneers in the use of plastics in aircraft construction, completes its first plane, the PT-160-K, a two-seat, open-tandem military trainer. The 35-foot-span plane, fitted with a 160-h.p. engine, uses Nuyon, a triple criss-cross laminated spruce plywood heavily impregnated with phenol formaldehyde. The sheets are formed to shape by the application of heat and pressure. The plane's skin is formed of two molded halves fitted over conventional spars and ribs and sealed at all points by the same phenol process. Flight, Dec. 21, 1939, p. 508.

100 Years Ago, December 1914

Dec. 24 The first bomb falls on England, dropped by a German aircraft over Dover. Francis K. Mason and Martin Windrow, Know Aviation, p. 17.

Career Opportunities

AUBURN UNIVERSITY

SAMUEL GINN
COLLEGE OF ENGINEERING

AEROSPACE

The Department of Aerospace Engineering at Auburn University invites applications for multiple tenure track positions at the assistant or associate professor rank. Candidates with exceptional background and experience may be considered at a higher rank. Areas of interest include air-breathing and rocket propulsion, aerospace structures and structural dynamics, aeroelasticity, computational fluid dynamics, and combustion. Other areas related to aerospace engineering may also be considered. Applicants must have an earned doctorate in aerospace engineering, mechanical engineering, or a closely related field.

Applicants are encouraged to apply as soon as possible by submitting a cover letter, current CV, research vision, teaching philosophy, and three references to the job posting at: http://aufacultypositions.peopleadmin.com/postings/711

Cover letters may be addressed to: Prof. Winfred A. (Butch) Foster, Faculty Search Committee Chair, 211 Davis Hall, Auburn, AL 36849. The review process will begin December 1, 2014, but applications will continue to be accepted until the position is filled. Additional information about the department may be found at: http://www.eng.auburn.edu/aero/

Auburn University is an EEO/Vet/Disability employer.

VirginiaTech
Invent the Future

Department of Mechanical Engineering Faculty Positions

The Department of Mechanical Engineering at Virginia Tech invites applications for four faculty positions: one in the area of Mechanical Systems and three in the area of Fluid Dynamics and Thermal Sciences. These positions will be at Assistant, Associate, or Full Professor levels. Exceptional candidates will be considered for named professorships.

The successful candidate for the Mechanical Systems position will have expertise in fields related to robotics, dynamics and control, mechatronics, machine learning, human-machine interaction, bio-robotics and medical robotics, robotic exoskeletons, or other emerging applications of robotics or autonomous systems.

The Fluid Dynamics and Thermal Sciences positions are targeted towards (1) Experimental combustion science and technology in novel propulsion and energy applications; (2) Fundamental and applied experimental fluid dynamics using advanced measurement techniques in emerging applications such as, but not limited to, energy harvesting, biological and bio-inspired systems; (3) Experimental or computational multiphase flow and heat transfer at the micro-nano scales in emerging energy and thermal management systems. Applicants in other emerging areas such as data analytics and uncertainty quantification in fluid-thermal engineered systems are also encouraged to apply.

Blacksburg is located in the Blue Ridge Mountains and is widely recognized by national rankings as a vibrant and desirable community with affordable living, world-class outdoor recreation, an active arts community, and a diverse international population. The Department of Mechanical Engineering which includes a Nuclear Engineering Program, has over 50 faculty, research expenditures in excess of $17M, and a current enrollment of over 170 doctoral, 130 masters, and over 1200 undergraduate students. The Department is ranked 16^{th} and 17^{th} out of all mechanical engineering departments in the nation in undergraduate and graduate education, respectively, by the 2014 U.S. News and World Report. The Department includes several research centers and its faculty members are engaged in diverse multidisciplinary research activities. The mechanical engineering faculty also benefit from a number of university-wide institutes such as the Institute for Critical Technology and Applied Science (ICTAS), College level centers such as the Rolls-Royce and the Commonwealth of Virginia Center for Aerospace Propulsion Systems (CCAPS), the recently established Rolls Royce University Technology Center (UTC) in advanced systems diagnostics, and the Virginia Center for Autonomous Systems (VaCAS, www.unmanned.vt.edu).

Applicants must hold a doctoral degree in engineering or a closely related discipline. We are seeking highly qualified candidates committed to a career in research and teaching. The successful candidate will be responsible for mentoring graduate and undergraduate students, teaching courses at the undergraduate and graduate levels, and developing an internationally recognized research program. Candidates should apply online at www.jobs.vt.edu to posting number TR0140100 for the Mechanical Systems position and to posting number TR0140101 for the Fluid Dynamics and Thermal Sciences positions. For the Fluid Dynamics and Thermal Science positions please indicate the research area you would like to be considered for in your cover letter. Applicants should submit a cover letter, a curriculum vitae including a list of published journal articles, a one-page research statement, a brief statement on teaching preferences, and the names of five references that the search committee may contact. Review of applications for all positions will begin on December 10, 2014 and will continue until the positions are filled.

Virginia Tech is committed to diversity and seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Virginia Tech is a recipient of the National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers (www.advance.vt.edu).

For assistance submitting the application please contact Ms. Brandy McCoy (brandy07@vt.edu), (540) 231-6661. General inquiries about the positions should be addressed to the search committee chairs: Prof. Andrew Kurdila (kurdila@vt.edu) for Mechanical Systems and Prof. Francine Battaglia (fbattagl@vt.edu) for Fluid Dynamics and Thermal Sciences

UNIVERSITY OF CENTRAL FLORIDA
MECHANICAL AND AEROSPACE ENGINEERING

Assistant/Associate Professor in Mechanical and Aerospace Engineering

In collaboration with the Townes Laser Institute and the College of Optics and Photonics, the Mechanical and Aerospace Engineering (MAE) Department of the College of Engineering and Computer Science (CECS), are establishing a new initiative in advanced manufacturing technologies.

As part of this initiative, the MAE Department is recruiting a tenure-track/tenured faculty member who can successfully build strong research and educational programs in sensors and advanced laser-based manufacturing technologies, establish new manufacturing facilities, and strengthen partnerships with relevant industries. Faculty associated with this initiative will benefit from the recently formed $250M International Consortium for Advanced Manufacturing Research (ICAMR) in Osceola County to develop innovative manufacturing of sensors and other high-tech products.

The Townes Laser Institute, housed in the College of Optics and Photonics, is one of the nation's premier academic research centers in advanced laser technologies and their applications. Its mission is to advance laser technologies that will impact applications in manufacturing, medicine and defense.

Interested persons with questions about the positions may contact the Search Committee Chair, Dr. Ranganathan Kumar, Associate Dean for Research, at Ranganathan.Kumar@ucf.edu. For more information about the department, we invite all interested parties to visit MAE's website at www.mae.ucf.edu. Candidates must submit all documents on-line to http://www.jobswithucf.com:80/postings/40092. Review of applications will begin immediately and continue until the positions are filled.

UCF is an equal opportunity, affirmative action employer and encourages the candidacies of women, members of racial and ethnic minorities, and persons with disabilities. All searches and documents are subject to the Sunshine and public records laws of the State of Florida.

AEROSPACE ENGINEERING AND MECHANICS
UNIVERSITY OF MINNESOTA

The Department of Aerospace Engineering and Mechanics seeks to fill faculty positions in aerospace systems. Applications are invited in all areas of aerospace systems, particularly in areas that complement current research activities in the department. These research activities include but are not limited to control system analysis and design, multi-sensor navigation and guidance algorithm design for the operation of aircraft, spacecraft and autonomous vehicles. The department has a large number of experimental and computational facilities. There are close ties with other departments and on-campus multidisciplinary centers. Information about the department is available at http://www.aem.umn.edu/

The successful candidate will participate in all aspects of the Department's mission, including teaching undergraduate and graduate courses in aerospace engineering mechanics and aerospace systems; supervision of undergraduate and graduate students; service responsibilities; and developing an independent, externally-funded research program.

Applicants must have an earned doctorate in a related field by the date of appointment. The intent is to hire at the assistant professor rank. However, exceptional applicants may be considered for appointment at the rank of associate professor with or without tenure. It is anticipated that the appointment will begin fall 2015.

To apply for this position, candidates must go to http://www1.umn.edu/ohr/employment/index.html and search for requisition no. 193904. Please attach your letter of application, detailed resume, names and contact information of three references, and a statement of teaching and research interests.

Application Deadline: The initial screening of applications will begin on December 1, 2014; applications will be accepted until the position is filled.

The University of Minnesota is an equal opportunity educator and employer.

UCLA Engineering

University of California, Los Angeles

Mechanical and Aerospace Engineering Department

The Mechanical and Aerospace Engineering Department is accepting applications to fill two full-time tenure track faculty positions at the Assistant Professor level in Mechanical and Aerospace Engineering Department. Exceptional candidates at the Associate or Full Professor level will also be considered.

The first position (Tracking #JPF00557) is in ***Aerospace Engineering***. Candidates should have demonstrated technical strength and research focus in the fundamentals that underlie advanced aeronautical and/or space systems. Candidates whose technical interests overlap with those in Southern California's extensive aerospace community are of particular interest. Please apply by submitting your materials via our online application site, https://recruit.apo.ucla.edu/apply/JPF00557.

The second position (Tracking #JPF00585) is in ***Distributed Transductions for Mechanical Systems***. Areas of interest include but are not limited to: distributed sensing and actuation that empower mechanical systems such as robots and wearable devices; adaptive transducers capable of changing bulk or surface properties; transduction network with local intelligence to reduce the signal bandwidth requirements; and emerging manufacturing technologies for such transducers. Please apply by submitting your materials via our online application site, https://recruit.apo.ucla.edu/apply/JPF00585.

Applicants must hold a doctoral degree in engineering or a closely related discipline. The successful candidate will be responsible for teaching undergraduate and graduate courses and for developing a strong externally sponsored research program. We are interested in outstanding candidates who are committed to excellence in teaching and scholarship and to a diverse campus climate. The University of California is an affirmative action/equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: UC Nondiscrimination & Affirmative Action Policy.

Applications will be accepted online while the submission site is open until June 15, 2015. The evaluation of applications will be rolling. The first evaluation will be conducted on applications submitted by January 5, 2015 and interviews of selected candidates will start thereafter. Do not send hard copies, as they will not be processed or returned.

FACULTY POSITIONS

THE DEPARTMENT OF AEROSPACE ENGINEERING & ENGINEERING MECHANICS AT THE UNIVERSITY OF TEXAS AT AUSTIN has four faculty positions open with a start date of September 2015. Our intention is that most of these positions will be hired at the assistant professor rank, but outstanding candidates at the rank of associate professor or early full professor will be considered. We invite applications in the following areas:

- **Remote Sensing.** Earth and space observation and associated technology and data analysis. Topics of interest include estimation, orbital mechanics, data fusion, modeling, and interpretation of remote sensing data. Application areas include Earth and planetary remote sensing, space situational awareness, and space geodesy. Collaboration is encouraged with the internationally-recognized Center for Space Research (**http://www.csr.utexas.edu/**), which is at the forefront of research into space science, engineering and technology.
- **Space Systems Engineering.** Engineering of small satellites and/or distributed space systems in support of Earth and space science and technology. Topics include autonomy, estimation and control, embedded systems, mission design, technology miniaturization, on-board algorithms and other emerging areas in space technology. Experience with space-flight projects is desired. Collaboration is encouraged with the internationally-recognized Center for Space Research (**http://www.csr.utexas.edu/**), which is at the forefront of research into space science, engineering and technology.
- **Robotic Systems.** Mobile robotic systems with application to air, space, sea or land vehicles. Research areas may include, but are not limited to, cognitive robotics (autonomy, machine learning, human-robot collaboration), bio-inspired systems, soft robotics, bio-mimetic vehicle dynamics, and computational neuroscience. Applicants with interests in large-scale cyber-physical systems or experimental efforts are particularly encouraged to apply. We seek synergies between successful applicants in multiple departments, thus a demonstrated ability to work across disciplines is essential.
- **Computational Fluid Dynamics.** Multi-scale modeling of turbulent flows relevant to propulsion, energy, combustion, unsteady aerodynamics, flow-structure interaction, bio-inspired locomotion, and the environment. The successful candidate will have expertise in modeling turbulent flows that have added complexity such as chemical reactions, plasma, surface interactions, flow-structure interaction, multiple phases, and geophysical phenomena. Computational resources are available through UT's Texas Advanced Computing Center (**https://www.tacc.utexas.edu/**) and collaboration is encouraged with UT's Institute for Computational Engineering and Sciences (**https://www.ices.utexas.edu/**)

The successful candidates for these positions are expected to supervise graduate students, teach undergraduate and graduate courses, develop sponsored research programs, collaborate with other faculty, and be involved in service to the university and the engineering profession. Applications received by **December 15, 2014** are assured full consideration, but the search will continue until the position is filled.

To apply, submit an application, CV, cover letter, research statement, teaching statement, and names and contact information for references (a minimum of 3 for tenure-track and 5 for tenured candidates) at **http://www.ae.utexas.edu/faculty/faculty-openings**. Only complete applications will be considered. Applicants for this position should have received, or expect to receive a doctoral degree prior to September 2015. The University of Texas at Austin is an affirmative action, equal opportunity employer. For more information about The Department of Aerospace Engineering and Engineering Mechanics, please visit **http://www.ae.utexas.edu**. These positions have been designated as security-sensitive, and a criminal background check will be conducted on the applicants selected.

What Starts Here Changes the World

MECHANICAL AND AEROSPACE ENGINEERING DEPARTMENT

NTT Assistant Teaching Professor (Ref #00061252)

The Department of Mechanical and Aerospace Engineering at the Missouri University of Science and Technology (formerly the University of Missouri-Rolla) invites applications for a non-tenure-track (NTT) teaching assistant professor position (exceptional candidates may be considered for a higher rank). NTT teaching faculty members contribute to the core activity of teaching and are expected to be fully engaged in the department's curriculum development and delivery. The successful candidate should have skills and experience that add value to the department's teaching mission. The initial appointment will be for one year and is potentially renewable for a multiple year appointment, with an expected affiliation with the department over an extended period.

Applicants for this position are expected to provide high-quality teaching at the undergraduate level in the area of design in mechanical and/or aerospace engineering. Examples of the courses that are expected to be taught include introduction to engineering design for general engineering students, introduction to mechanical design, aircraft/spacecraft design, and other design courses at higher levels. As NTT teaching faculty at Missouri S&T may be promoted, it is anticipated that the successful candidate would achieve a sustained level of recognition by students and peers as a stimulating, inspiring and effective teacher, as well as develop excellence in the production of effective learning materials, improved teaching techniques, and state-of-the-art delivery systems. The typical workload for this position is four (3 credit hour) courses per semester during the academic year. The position may include laboratory supervisory responsibilities, undergraduate advising, or professional and service activities related to the teaching assignment. It is expected that the teaching assignments will be a minimum of 75% of the workload of this position.

An earned doctorate in Mechanical or Aerospace Engineering, or closely related field, is required for this position. Ability to teach at the undergraduate level in a variety of areas of mechanical/aerospace engineering is desired, with particular interest in teaching in the area of design. Successful prior teaching experience will be an important consideration, and industrial experience is also desirable.

The department currently has 38 full-time faculty members (three of which are teaching faculty), over 800 undergraduate and approximately 200 graduate students. The Department offers the B.S., M.S., and Ph.D. degrees in both Mechanical and Aerospace Engineering. A recently completed $29 million construction and renovation project has produced a state-of-the-art Mechanical and Aerospace Engineering complex with 144,000 square feet of teaching and research laboratory space. Details regarding the department can be found at http://mae.mst.edu.

The search committee will begin the review process immediately upon receipt of applications, and the search will remain open until the position is filled. Please submit an application consisting of a current curriculum vitae, a statement of teaching interests and philosophy, and contact information for five professional references. All application materials must be electronically submitted to Missouri S&T's Human Resource Office at: http://hraadi.mst.edu/hr/employment/. Acceptable electronic formats that can be used for email attachments include PDF and Word; hardcopy application materials will not be accepted.

The final candidate is required to provide official transcript(s) for any college degree(s) listed in application materials submitted. Copies of transcript(s) must be provided prior to the start of employment. In addition, the final candidate may be required to verify other credentials listed in application materials. Failure to provide official transcript(s) or other required verification may result in the withdrawal of the job offer.

Missouri S&T is an AA/EO Employer and does not discriminate based on race, color, religion, sex, sexual orientation, national origin, age, disability, or status as Vietnam-era veteran. Females, minorities, and persons with disabilities are encouraged to apply. Missouri S&T is responsive to the needs of dual-career couples. Missouri University of Science and Technology participates in E-Verify. For more information on E-Verify, please contact DHS at: 1-800-464-3218.

NOTE: All application materials must refer to position reference number (R00061252) in order to be processed.

Faculty Position in Engineering and Ethics of Unmanned Aircraft Systems

The Pennsylvania State University (www.psu.edu) is embarking on a transformative series of co-funded hires in ethics designed to ensure that Penn State becomes a leader in ethics-informed interdisciplinary research and the integration of ethical literacy throughout the curriculum.

The Department of Aerospace Engineering and the Rock Ethics Institute (the "Rock") invite nominations and applications for an open-rank tenure-track position starting in 2015. The Department seeks an outstanding individual who is committed to undergraduate and graduate education and to the establishment of an externally-funded research program that supports graduate education. Candidates must possess technical expertise related to the design and engineering of unmanned air vehicles and systems, as well as demonstrable complementary interests in the societal and ethical aspects of such systems. The Department seeks to build on its strengths to expand into new areas—candidates who can contribute to interdisciplinary and collaborative programs involving UAS and ethics are of primary interest. The research area represented by this search could be viewed as a special aspect of a broader one at the intersection of robotics, autonomy, and ethics. Applicants must have an earned doctorate in aerospace engineering or a related field; at least one degree in aerospace engineering or related experience is preferred. Responses received before January 2015 are assured full consideration, but the search will remain open until the position is filled. Applicants should submit electronically a single pdf file to job #54151 at **http://apptrkr.com/533093** . The file should contain: a cover letter; a CV; statements of research and teaching interests; a statement of how the candidate's work is relevant to the Rock's vision and how such a position would enhance their own work; and the names and contact information for at least three references.

This is one of twelve tenure-track appointments funded by the University to augment the Penn State mission in the important area of ethics. Co-funded faculty members will be hosted as affiliates of the Penn State Rock Ethics Institute (rockethics.psu.edu). We seek candidates who will build on the Rock's tradition of excellence in collaborative, interdisciplinary ethics research and ethically informed decision support for significant societal issues, as well as its success in integrating ethics into the curriculum. We seek individuals who will be effective working on and leading interdisciplinary teams that embed ethical analysis into research projects, including decision support research, and who have experience and interest in integrating ethics in curricula. In order to enhance collaboration with faculty and students on existing ethics research and curricular initiatives as well as building new initiatives and programs in conjunction with the Institute's mission, co-funded faculty members will receive a one-course teaching release for the first five years.

Penn State at University Park is a land-grant institution located within the beautiful Appalachian mountains of central Pennsylvania. State College and nearby communities within Centre County are home to roughly 100,000 people, including over 40,000 students, and offer a rich variety of cultural, recreational, educational, and athletic activities. State College is a wonderful community offering a high quality of life.

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/ , which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to minorities, women, veterans, disabled individuals, and other protected groups.

PENNSTATE

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FACULTY POSITION
DEPARTMENT OF AEROSPACE ENGINEERING
TEXAS A&M – DWIGHT LOOK COLLEGE OF ENGINEERING

The Department of Aerospace Engineering in the Dwight Look College of Engineering is continuing to strategically increase in size and strength. This year, the department invites applications for an open-rank tenure-track position from exceptional individuals who have demonstrated expertise in aerothermal sciences with applications to aerospace systems. The successful applicant will be expected to teach at the undergraduate and graduate levels, develop an independent, externally funded research program, advise graduate students, participate in all aspects of the department's mission, and serve the profession.

Texas A&M is located in the twin cities of Bryan and College Station, with a population of more than 175,000, and is conveniently located in a triangle formed by Dallas, Houston and Austin. Texas A&M has more than 50,000 graduate and undergraduate students enrolled. Research expenditures at Texas A&M total more than $820 million annually, ranking in the top tier of universities nationwide. With an endowment valued at more than $5 billion, the university ranks fourth among U.S. public universities and 10th overall. With 380 tenured/tenure-track faculty members and more than 12,000 students, the Dwight Look College of Engineering is one of the largest engineering schools in the country. The college is ranked seventh in graduate studies and eighth in undergraduate programs among public institutions by *U.S. News & World Report*, with seven of the college's 13 departments ranked in the Top 10. The Look College is ranked second in research expenditures by the American Society for Engineering Education.

The Department of Aerospace Engineering was formed in 1940. It has 34 core faculty members, 6 jointly appointed faculty members, including 3 National Academy of Engineering Members. We currently enjoy an enrollment of over 700 undergraduate and 150 graduate students. Our students are offered a modern curriculum that is balanced across the three principal disciplines of aerospace engineering: aerodynamics and propulsion, dynamics and control, and materials and structures. In recent years, the department has built a strong national program based on the quality of its faculty and programs; among public institutions, its graduate aerospace engineering program ranks 7th in the most recent *U.S. News & World Report* rankings. More information about the department is available at http://engineering.tamu.edu/aerospace.

Applicants who apply a balanced approach among experiment, computation, and theory are especially encouraged to apply. The successful candidate will have the opportunity to collaborate with renowned colleagues whose research thrust areas include transition and turbulence, combustion and propulsion, multifunctional and extreme-environment materials, advanced and high-performance computations and diagnostics, autonomous systems, space systems and satellites, and high-speed vehicle systems. Aerospace Engineering is also home to unique and nationally important experimental facilities, including advanced instrumentation and diagnostics.

Applicants must have earned a doctorate in aerospace engineering or a closely related field.

Applicants should submit a cover letter, curriculum vitae, teaching statement, research statement, and a list of five references (including postal addresses, phone numbers and email addresses) by applying for this specific position at www.tamengineeringjobs.com. Full consideration will be given to applications received by January 20, 2015. Applications received after that date may be considered until positions are filled. It is anticipated the appointment will begin fall 2015.

The members of Texas A&M Engineering are all Affirmative Action/Equal Employment Opportunity Employers. It is the policy of these members in all aspects of operations each person shall be considered solely on the basis of qualifications, without regard to race, color, sex, religion, national origin, age, disabilities or veteran status.

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AIAA welcomes suggestions from members
on how we can better serve you.
All comments will be acknowledged.
We will do our best to address issues
that are important to our membership.
Please send your comments to:

Merri Sanchez
VP Member Services
AIAA
1801 Alexander Bell Drive, Suite 500
Reston, VA 20191-4344

AIAA

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I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form 3526, August 2012 (Page 2 of 3)

AIAA Bulletin

In October, AIAA Executive Director Sandy Magnus gave a presentation entitled "Perspectives from Space" at an AIAA Carolina Section dinner at the Boeing South Carolina's 787 Dreamliner Final Assembly Tour Balcony in North Charleston, SC. (More information on page **B5**)

DECEMBER 2014

AIAA Directory

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1801 Alexander Bell Drive, Suite 500
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* Also accessible via Internet. Use the formula first name last initial@aiaa.org. Example: megans@aiaa.org.

† U.S. only. International callers should use 703/264-7500.

Addresses for Technical Committees and Section Chairs can be found on the AIAA Web site at **http://www.aiaa.org**.

We are frequently asked how to submit articles about section events, member awards, and other special interest items in the *AIAA Bulletin*. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the *AIAA Bulletin* Editor.

Event & **Course** Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
2015			
3–4 Jan	**Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-On Training Using CIFER®**	Kissimmee, FL	
3–4 Jan	**Best Practices in Wind Tunnel Testing**	Kissimmee, FL	
3–4 Jan	**Third International Workshop on High-Order CFD Methods**	Kissimmee, FL	
4 Jan	**Introduction to Integrated Computational Materials Engineering**	Kissimmee, FL	
5–9 Jan	**AIAA SciTech 2015 (AIAA Science and Technology Forum and Exposition)** **Featuring:** **23rd AIAA/AHS Adaptive Structures Conference** **53rd AIAA Aerospace Sciences Meeting** **AIAA Atmospheric Flight Mechanics Conference** **AIAA Infotech@Aerospace Conference** **2nd AIAA Spacecraft Structures Conference** **AIAA Guidance, Navigation, and Control Conference** **AIAA Modeling and Simulation Technologies Conference** **17th AIAA Non-Deterministic Approaches Conference** **56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **8th Symposium on Space Resource Utilization** **33rd Wind Energy Symposium**	Kissimmee, FL	**2 Jun 14**
8–9 Jan	**Fundamentals and Applications of Modern Flow Control**	Kissimmee, FL	
11–15 Jan†	**25th AAS/AIAA Space Flight Mechanics Meeting**	Williamsburg, VA (Contact: AAS—Roberto Furfaro, 520.312.7440; AIAA—Stefano Casotto, Stefano.casotto@unipd.it; http://space-flight.org/docs/2015_winter/2015_winter.html)	**15 Sep 14**
26–29 Jan†	**61st Annual Reliability & Maintainability Symposium (RAMS 2015)**	Palm Harbor, FL (Contact: Julio Pulido, 952 270 1630, julio.e.pulido@gmail.com, www.rams.org)	
7–14 Mar†	**2015 IEEE Aerospace Conference**	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	
8–9 Mar	**Overview of MIssile Design and System Engineering**	Laurel, MD	
10–12 Mar	**AIAA DEFENSE 2015 (AIAA Defense and Security Forum)** **Featuring:** **AIAA Missile Sciences Conference** **AIAA National Forum on Weapon System Effectiveness** **AIAA Strategic and Tactical Missile Systems Conference**	Laurel, MD	**4 Nov 14**
11 Mar	**AIAA Congressional Visits Day**	Washington, DC	
25–27 Mar†	**3rd Int. Conference on Buckling and Postbuckling Behaviour of Composite Laminated Shell Structures with DESICOS Workshop**	Braunschweig, Germany (Contact: Richard Degenhardt, +49 531 295 3059, Richard.degenhardt@dlr.de, www.desicos.eu	
30 Mar–2 Apr	**23rd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar**	Daytona Beach, FL	**30 Sep 14**
30 Mar–1 Apr†	**50th 3AF Conference on Applied Aerodynamics – Forthcoming Challenges for Aerodynamics**	Toulouse, France (Contact: Anne Venables, +33 1 56 64 12 30, Secr.exec@aaaf.asso.fr, www.3af-aerodynamics2015.com)	
13–15 Apr†	**EuroGNC 2015, 3rd CEAS Specialist Conference on Guidance, Navigation and Control**	Toulouse, France (Contact: Daniel Alazard, +33 (0)5 61 33 80 94, alazard@isae.fr, w3.onera.fr/eurognc2015)	
13–17 Apr†	**2015 IAA Planetary Defense Conference**	Frascati, Italy (Contact: William Ailor, 310.336.1135, william.h.ailor@aero.org, www.pdc2015.org)	
6 May	**Aerospace Spotlight Awards Gala**	Washington, DC	
25–27 May†	**22nd St. Petersburg International Conference on Integrated Navigation Systems**	St. Petersburg, Russia, (Contact: Prof. V. G. Peshekhonov, 7 812 238 8210, icins@eprib.ru, www. Elektropribor.spb.ru)	
4 Jun	**Aerospace Today ... and Tomorrow—An Executive Symposium**	Williamsburg, VA	
16–19 Jun†	**7th International Conference on Recent Advances in Space Technologies – RAST 2015**	Istanbul, Turkey (Contact: Capt. M. Serhan Yildiz, +90 212 6632490/4365, syildiz@hho.edu.tr or rast2015@rast.org.tr)	

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
22–26 Jun	**AIAA AVIATION 2015 (AIAA Aviation and Aeronautics Forum and Exposition)** **Featuring:** **21st AIAA/CEAS Aeroacoustics Conference** **31st AIAA Aerodynamic Measurement Technology and Ground Testing Conference** **33rd AIAA Applied Aerodynamics Conference** **AIAA Atmospheric Flight Mechanics Conference** **7th AIAA Atmospheric and Space Environments Conference** **15th AIAA Aviation Technology, Integration, and Operations Conference** **AIAA Balloon Systems Conference** **AIAA Complex Aerospace Systems Exchange** **22nd AIAA Computational Fluid Dynamics Conference** **AIAA Flight Testing Conference** **45th AIAA Fluid Dynamics Conference** **22nd AIAA Lighter-Than-Air Systems Technology Conference** **16th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference** **AIAA Modeling and Simulation Technologies Conference** **46th AIAA Plasmadynamics and Lasers Conference** **45th AIAA Thermophysics Conference**	Dallas, TX	**13 Nov 14**
28 Jun–2 Jul†	**International Forum on Aeroelasticity and Structural Dynamics (IFASD)**	Saint Petersburg, Russia (Contact: Dr. Svetlana Kuzmina, +7 495 556-4072, kuzmina@tsagi.ru, www.ifasd2015.com)	
6–9 Jul	**20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference**	Glasgow, Scotland	**8 Dec14**
12–16 Jul†	**International Conference on Environmental Systems**	Bellevue, WA (Contact: Andrew Jackson, 806.834.6575, Andrew.jackson@ttu.edu, www.depts.ttu.edu/ceweb/ices)	
27–29 Jul	**AIAA Propulsion and Energy 2015 (AIAA Propulsion and Energy Forum and Exposition)** **Featuring:** **51st AIAA/SAE/ASEE Joint Propulsion Conference** **13th International Energy Conversion Engineering Conference**	Orlando, FL	**7 Jan 15**
9–13 Aug†	**2015 AAS/AIAA Astrodynamics Specialist Conference**	Vail, CO (Contact: Dr. W. Todd Cerven, william.t.cerven@aero.org, www.space-flight.org/docs/2015_astro/2015_astro.html)	
31 Aug–2 Sep	**AIAA SPACE 2015 (AIAA Space and Astronautics Forum and Exposition)**	Pasadena, CA	**10 Feb 15**
7–10 Sept†	**33rd AIAA International Communications Satellite Systems Conference and Exhibition (ICSSC-2015)**	Gold Coast, Australia (Contact: Geri Geschke, +61 7 3414 0700, Geri.geschke@emsolutions.com.au, www.satcomspace.org)	
12–16 Oct†	**66th International Astronautical Congress, Jerusalem, Israel**	(Contact: www.iac2015.org)	
2016			
4–8 Jan	**AIAA SciTech 2016 (AIAA Science and Technology Forum and Exposition)** **Featuring:** **24th AIAA/AHS Adaptive Structures Conference** **54th AIAA Aerospace Sciences Meeting** **AIAA Atmospheric Flight Mechanics Conference** **15th Dynamics Specialists Conference** **AIAA Guidance, Navigation, and Control Conference** **AIAA Infotech@Aerospace Conference** **AIAA Modeling and Simulation Technologies Conference** **18th AIAA Non-Deterministic Approaches Conference** **57th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **9th Symposium on Space Resource Utilization** **4th AIAA Spacecraft Structures Conference** **34th Wind Energy Symposium**	San Diego, CA	

For more information on meetings listed above, visit our website at www.aiaa.org/calendar or call 800.639.AIAA or 703.264.7500 (outside U.S.).

†Meetings cosponsored by AIAA. Cosponsorship forms can be found at https://www.aiaa.org/Co-SponsorshipOpportunities/.

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START YOUR YEAR OFF RIGHT AT AIAA SCITECH 2015

At the beginning of every new year, friends and colleagues frequently gather together to reflect on the past, discuss the present, and dream of the future—and our aerospace community is no different. We will gather at the AIAA Science and Technology Forum and Exposition (AIAA SciTech 2015) in Kissimmee, Florida, from 5–9 January to do exactly that as we take part in the world's largest gathering of aerospace professionals. AIAA SciTech 2015 will bring together more than 3,000 participants from 40 countries, representing over 700 institutions, and featuring 2,500 technical papers across hundreds of fields of study. The event combines 11 individual technical conferences under one roof in vibrant and temperate central Florida—a short drive from the Kennedy Space Center and surrounded by some of the world's top tourist destinations. AIAA SciTech 2015 will convene the best and brightest from industry, academia, and government. It is the ideal place to engage with colleagues within your discipline and to interact with experts in other disciplines, all in an effort to shape the future of aerospace.

Whatever your role in our community is—engineer, program manager, scientist, executive, student, educator, analyst, policymaker, or any of the thousands of other positions that make aerospace so exciting—AIAA SciTech 2015 will offer you conversation, collaboration, insight, and inspiration that will help us kick off another amazing year of exploration, discovery, and innovation. Since last January we have worked to design a stellar program that combines frank discussions about the state of our industry, a detailed analysis of the prospects for the future, and deep insight into the emerging technology and programs that can make that future successful.

AIAA SciTech 2015's plenary sessions will tackle some of the most critical questions facing the future of our community: What should our nation's science and technology policies be? How will emerging actors in the international aerospace community drive competition and technology advancement? What is the future of design in our community—and what are we likely to see in the years ahead as technology and scientific knowledge continue to evolve? How can we assure that the future workforce will be diverse, vibrant, and able to meet the future needs of employers? Each of these subjects is vital to understanding the future of our community, and the chance to learn about all of them, in the same place, in the same week, is a unique opportunity available to you only at AIAA SciTech 2015.

Those plenary-level discussions will be explored in more depth in our dynamic Forum 360 sessions. Topics will include how "Big Data" will impact aerospace, how aerospace can help ensure "environmental security," how the "Digital System Model" will transform the future of acquisition, and how the explosion of information and communication technology will shape the direction of aerospace science and technology and help more people connect and collaborate across great distances. These Forum 360 sessions will give you valuable information and insight that you can harness to make an immediate impact on the work you do every day.

The technical sessions will ensure you are in-the-know about the latest cutting-edge research and innovative thinking happening in our community. Featuring more than 2,500 papers—across 300 topics areas—these presentations and talks will educate, inform, and engage students and professionals alike.

The networking sessions are perfect opportunities to connect or reconnect with peers across the industry—allowing students, young professionals, and seasoned veterans to share advice and perspectives that will help each of us grow. Only SciTech 2015 will offer attendees, especially our student and young professional attendees, a chance to mix and mingle with the thought leaders of our community. We are also offering our Rising Leaders program, a collection of networking, mentoring, and informational events aimed at helping young professionals gain the skills, knowledge, and confidence needed to further their careers. Surveys show that 68% of attendees immediately benefited from these opportunities to build/form new connections and gain new insight into persistent challenges.

AIAA SciTech 2015 will also afford us opportunities to celebrate our community's successes. Recognition events include the induction of our new Associate Fellows, our award luncheons, and our distinguished award lectures. At these events, we will be able to fully celebrate the exciting and inspiring achievements of our coworkers, friends, and community members.

Join us at AIAA SciTech 2015—the best venue for all of us to gather and celebrate the opportunity of another year for our community to better the world, and to plan and work together to make 2015 our community's best year yet. For more information and to register, please visit **www.aiaa-scitech.org**. We hope to see you in Kissimmee!

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Purdue University

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Chief Technologist
The Boeing Company

AIAA CAROLINA SECTION HOSTS DINNER MEETING AT BOEING SOUTH CAROLINA

On 22 October, the AIAA Carolina Section hosted a dinner meeting at Boeing South Carolina's 787 Dreamliner Final Assembly Tour Balcony in North Charleston, SC. Sandy Magnus, AIAA Executive Director and a former NASA astronaut, gave an informative presentation entitled "Perspectives from Space" to the 64 attendees. Attendees included AIAA members and nonmembers from area businesses, including Boeing, Lockheed Martin, Google, Amazon, and ATK, as well as professors and students from The Citadel and University of South Carolina. The AIAA Public Policy Committee (PPC) held its annual meeting at Boeing's Welcome Center earlier in the day, and the committee members participated in the dinner to show their support of the AIAA Carolina Section.

AIAA ANNOUNCES ASSOCIATE FELLOWS CLASS OF 2015

AIAA is pleased to announce the selection of the AIAA Associate Fellows class of 2015. The 147 new Associate Fellows will be honored at the AIAA Associate Fellows Recognition Ceremony and Dinner on Monday, 5 January 2015, at the Gaylord Palms and Convention Center, Kissimmee, Florida, in conjunction with AIAA SciTech 2015.

"AIAA congratulates the newly announced class of Associate Fellows for 2015," said AIAA President Jim Albaugh. "Each of these individuals has made unique contributions to aerospace and each serves as an example of how engineers make the world a better place each and every day. AIAA wishes them the best on their continued careers, and we are excited to see the advances they will bring next."

"AIAA Associate Fellows have devoted their careers to shaping the future of aerospace, investing long hours and years of work to achieve milestones that are often thought to be impossible," said AIAA Executive Director Sandy Magnus. "AIAA congratulates the 2015 class of Associate Fellows and thanks them for their dedication to advancing the known limits of flight and space engineering and science ever forward."

To be selected for the grade of Associate Fellow an individual must be an AIAA Senior Member for at least twelve months prior to the current deadline for Associate Fellow nomination, with at least twelve years professional experience, and be recommended by three current Associate Fellows. The new Associate Fellows are:

David Akin, University of Maryland
Steven Allmaras, Massachusetts Institute of Technology
Richard Anthony, U.S. Air Force Research Laboratory (AFRL)
Russell Averill, The Aerospace Corporation
Brian Beal, U.S. Air Force Research Laboratory
Robert Bell, Sierra Nevada Corporation
Dale Belter, The Boeing Company
Michael Benjamin, GE Aviation - General Electric Company
Marc Bernstein, Massachusetts Institute of Technology—Lincoln Laboratory
Naipei Peter Bi, Naval Surface Warfare Center Carderock Division
Warren Boley, Aerojet Rocketdyne
Mary Bowden, University of Maryland
Isaac Boxx, Institute of Combustion Technology, German Aerospace Center
Robert Boyd, Lockheed Martin Corporation
Tsutsumi Sophia Bright, The Boeing Company
Eric Butte, Lockheed Martin Corporation
Orlando Carvalho, Lockheed Martin CorporationChristopher Chadwick, The Boeing Company
Chau-Lyan Chang, NASA Langley Research Center
Carissa Bryce Christensen, The Tauri Group
Peter Coen, NASA Langley Research Center
Douglas Cook, Jacobs Technology Inc.
Luis Crespo, National Institute of Aerospace
Brett Cruden, NASA Ames Research Center
Christopher Culbert, NASA Johnson Space Center
Anubhav Datta, Science & Technology Corporation
Nancy Jan Davis, Jacobs Technology Inc.
Manuel De Ponte, The Aerospace Corporation
Edward Dickes, Bihrle Applied Research, Inc
Mary Lynne Dittmar, Dittmar Associates Inc.
Christopher D'Souza, NASA Johnson Space Center
Earl Duque, Intelligent Light
Naveed Durrani, Institute of Space Technology
Wayne Elbers, Lockheed Martin Corporation
Paul Engola, Lockheed Martin Corporation
Steven Everett, The Boeing Company
Scott Fancher, The Boeing Company
Walter Fichter, University of Stuttgart
Dennis Finley, Lockheed Martin Corporation
John Foreman, Software Engineering Institute
William Fourney, University of Maryland
Charles Fremaux, NASA Langley Research Center
John Fuller, Aurora Flight Sciences
Stephen Gaddis, NASA Langley Research Center
Karl Garman, Federal Aviation Administration
Jeff Gramling, NASA Goddard Space Flight Center
David Greenblatt, Technion – Israel Institute of Technology
Robert Gregg, The Boeing Company
Charles Gustafson, The Aerospace Corporation
Stanley Gustafson, The Aerospace Corporation
Thomas Hannigan, Mississippi State University
Jill Hardash, Booz Allen Hamilton
Hamid Hefazi, Florida Institute of Technology
Florian Holzapfel, Technische Universitaet Muenchen
James Humbert, University of Maryland
William Humphreys, NASA Langley Research Center
Mark Jackson, Charles Stark Draper Laboratory
Richard Jaffe, NASA Ames Research Center
Jonathan Mark Janus, Mississippi State University
Donald Jaworske, NASA Glenn Research Center
Christopher Jones, Northrop Grumman Corporation
Thomas Joslyn, U.S. Air Force Academy
Nicole Key, Purdue University
Scott Klavon, SAE International
Monte Kopke, Lockheed Martin Corporation
Curt Kothera, InnoVital Systems Inc.
Robert Kraus, U.S. Air Force Academy
William Krenz, The Aerospace Corporation
Norbert Kroll, The German Aerospace Center
Jason Kuchera, Lockheed Martin Corporation
Rajan Kumar, Florida State University
Laurette Lahey, The Boeing Company
Tracy Lamm, Lockheed Martin Corporation
Michael LaPointe, NASA-Marshall Space Flight Center
Oliver Leembruggen, Booz Allen Hamilton
Elizabeth Lee-Rausch, NASA Langley Research Center
Sanjiva Lele, Stanford University
Ye Li, National Wind Technology Center
Kevin Lowe, Virginia Polytechnic Institute and State University
Wolfram Lunscher, COM DEV
Lester Lyles, The Lyles Group
Arup Maji, University of New Mexico
Cindy Malawy, The Boeing Company
Alexandre Martin, University of Kentucky
Leigh McCue, Virginia Polytechnic Institute and State University
Douglas McKinnon, Lockheed Martin Corporation
Michelle McMillan, SynGenics Corporation
Michael McWithey, Lockheed Martin Corporation
Hua Meng, Zhejiang University
David Mindell, Massachusetts Institute of Technology
Piero Miotto, Charles Stark Draper Laboratory
Howard Mitchell, The Aerospace Corporation
Padraig Moloney, Lockheed Martin Corporation
Sivakumaran Nadarajah, McGill University

Sameer Naik, Purdue University
Ali Najafi, ANSYS, Inc.
Andrew Neely, University of New South Wales
Eric Nielsen, NASA Langley Research Center
Michael Niestroy, Lockheed Martin Corporation
Fred Nitzsche, Carleton University
John Olson, Sierra Nevada Corporation
Juliet Page, Wyle Laboratories, Inc.
Michael Philen, Virginia Polytechnic Institute and State University
Dawn Phillips, NASA Marshall Space Flight Center
Orval Powell, U.S. Air Force Academy
Charles Precourt, ATK Space Systems
Marco Quadrelli, Jet Propulsion Laboratory
Rolf Radespiel, Technical University of Braunschweig
Raul Radovitzky, Massachusetts Institute of Technology
Joshua Rovey, Missouri University of Science & Technology
Kristin Rozier, NASA Ames Research Center
Eric Ruggiero, General Electric Company
Ryan Russell, University of Texas at Austin
Oussama Safadi, University of Southern California
Rahul Saha, Orbital Sciences Corporation
Barbara Sande, Lockheed Martin Corporation
Paul Savage, Strapdown Associates, Inc.
Robert Schunk, Utah State University
James Sergeant, Lockheed Martin Corporation
Suneel Ismail Sheikh, ASTER Labs, Inc.
Sarah Shull, NASA Johnson Space Center
Jayant Sirohi, University of Texas at Austin
John Sordyl, Williams International
Zoltan Spakovszky, Massachusetts Institute of Technology
Rani Warsi Sullivan, Mississippi State University
Xiaofeng Sun, Beijing University of Aeronautics and Astronautics
Jeffrey Sutton, Ohio State University
Sergei Tanygin, Analytical Graphics, Inc.
Ashish Tewari, Indian Institute of Technology, Kanpur
Michael Thacker, Textron Aviation
Mark Thomson, Jet Propulsion Laboratory
Vikas Tomar, Purdue University
John Robert Troeltzsch, Ball Aerospace & Technologies Corporation
Christopher Raymond Tschan, The Aerospace Corporation
William Vantine, ARES Corporation
Sagar Vidyasagar, Lockheed Martin Corporation
Charles Vono, Northrop Grumman Technical Services
Eric Walker, NASA Langley Research Center
Craig Wanke, The MITRE Corporation
Jonathan Watmuff, RMIT University
Mingjun Wei, New Mexico State University
Kyle Wetzel, Wetzel Engineering, Inc. & Wetzel Blade LLC
William Wood, NASA Langley Research Center
Azer Philip Yalin, Colorado State University
Sherrie Zacharius, The Aerospace Corporation
Christopher Michael Zeller, Ball Aerospace & Technologies Corporation
Xinguo Zhang, Aviation Industry Corporation of China (AVIC)

For more information on the AIAA Associate Fellows program, please contact Patricia A. Carr at triciac@aiaa.org, or 703.264.7523.

AAAF–AIAA RELATIONS

Interview by Jean-Pierre Sanfourche (3AF) with Mireille Gerard (former Director, International Activities, AIAA) regarding the history of collaboration between the Association Aeronautique et Astronautique de France (3AF) and AIAA. Translated from French.

Jean-Pierre Sanfourche (JPS): I suppose that if the French association is called … Aeronautique et Astronautique …, it is to use similar semantics as in AIAA?

Mireille Gerard (MG): It is quite possible that the two merging French associations were inspired by AIAA to select their new name, all the more so since the two words: “aeronautique” and “astronautique” were part of their initial titles.

JPS: What year did the first contact between AIAA and AAAF take place?

MG: I do not recall precisely. ... However, I remember well a specific contact which took place before the merger in 1971. A sizable delegation from AIAA, led by James J. Harford, Executive Director, came to Paris in 1963, and met officials from the Societe Francaise d’Astronautique (SFA). This was on the occasion of the 14th Congress of the International Astronautical Federation, hosted by the SFA in the UNESCO building. The major attraction of the Congress was the presence of Yuri Gagarin!

JPS: Is there a Memorandum of Understanding?

MG: Yes, a Memorandum of Understanding (MOU) between AIAA and 3AF was signed in June 2007 by AIAA Vice President–International Vincent Boles and 3AF President Dr. Michel Scheller at the Paris Air Show that year. The MOU calls for cooperation and collaboration in the following areas: “information exchange, organization and hosting of conferences and workshops, participation in student events, and other topics of mutual interest”.

Leaders from AIAA and 3AF meet periodically at a high level to discuss continued collaboration. The last such meeting was in April 2012 ... Prior meetings included a visit by AIAA Presidents Roger Simpson in 2006 and David Thompson in October 2009.

JPS: Can you speak to past and current cooperation and collaboration?

MG: Since 2005, 3AF and AIAA have co-organized the Aircraft Noise and Emissions Reduction Symposium (ANERS), a high-level, multidisciplinary technical forum that brings together leading engineers, scientists, government and civil aviation officials, corporate entities and policymakers to discuss topics and issues of aircraft noise and emissions reduction. The symposium rotates between France and the United States.

In 2012 in Tours, 3AF hosted the AIAA International Space Planes and Hypersonic Systems and Technology Conference. A new business model was put in place on that occasion. 3AF organized the conference. AIAA provided the use of its abstract/manuscript management and registration systems, as well as marketing and registration support, in addition to publishing the conference proceedings.

... collaboration has been ongoing between the two associations since their creation. Currently AIAA has 265 professional members from France, including 19 Associate Fellows, 6 Fellows and 2 Honorary Fellows: Jean-Pierre Marec (2003) and Pierre Betin (2004). There are also 5 French corporate members, and 47 student members. AIAA Technical Committees include 20 French members....Over the years, the number of French attendees and French paper presentations at AIAA technical conferences was the most significant among non-U.S. participation.

On the international scene, AIAA and 3AF delegations to the general assemblies of the International Astronautical Federation and the International Council of the Aeronautical Sciences always consulted each other when decisions needed to be made regarding the future of these two international organizations.

JPS: Who are the AAAF personalities who have played a significant role in the history of our relationship?

MG: Besides the presidents, executive directors and secretaries of the two associations, the four persons who have played a most significant role, in my opinion, are Marcel Pouliquen, Jean-Michel Contant, Pierre Betin and Christian Mari. Each one in his own way, made very important contributions to the development of the relationship over a period of many years.

Marcel Pouliquen, responsible for space affairs at SEP, then SNECMA, was one the first French members of the AIAA Space Transportation Technical Committee (STTC). He arranged the first visit of STTC members to France. He was particularly active in encouraging promising young French professionals to join AIAA TCs. He organized numerous internships and exchanges of student members between the two countries.

As Secretary General for 10 years and then Vice President on the 3AF Bureau, Jean-Michel Contant strongly encouraged bilateral cooperation between the two associations, leading to the MOU, to the joint conferences, and to the Annonay celebration. He has been an active member and participant in the discussions of the AIAA International Activities Committee. He has been a long-time member of the Editorial Board of *Aerospace America*.

Pierre Betin played a unique role in initiating and organizing many contacts between French and U.S. aerospace industry executives within the framework of AIAA and 3AF. He fostered French attendance and presentation of papers at AIAA conferences. Together with 3AF and AIAA, he organized a visit of U.S. aerospace leadership to French industrial companies and government organizations in 1999. He was the first non-U.S. member of the AIAA Board of Directors and the Institute Development Committee. For the past 15 years, he has been a member of the AIAA Fellows Selection Committee and then the Honorary Fellows Selection Committee.

Christian Mari, Vice President, Recherche et Technologie at Messier-Dowty-Bugatti, and 3AF Vice President, is now the liaison between the two associations on the AIAA International Activities Committee. He was an active member of the AIAA Board of Directors, and served two terms as Director-at-Large, International, from 2004 to 2010.

JPS: What role did you personally play in the development of AAAF-AIAA relationship?

MG: I was very instrumental in the creation of the AIAA International Activities Committee at a time when collaboration and cooperation were not quite “the norm of the day” between the two countries. I played a proactive role within this Committee which includes U.S. and non-U.S. members whose vision was to develop cooperation and collaboration with sister associations and global outreach.

JPS: Some outstanding events of this cooperation?

MG: The key one ... is the signing of the [MOU].

The Propulsion Tour of 1999 was also one of these outstanding events. As Directeur General Adjoint, SNECMA, at the time, Pierre Betin played a prominent role. Fifteen leaders of the U.S. aerospace community, led by E.C “Pete” Aldridge, Jr. and Robert L. “Bob” Crippen, came to France ... to visit a number of French institutions including SNECMA, SEP, SNPE and CNRS....

Another significant event was the First Historic Site commemoration in the city of the Montgolfier brothers in Annonay, France in 2002. Joseph and Etienne captured the world’s imagination with their first balloon flight from the Place des Cordeliers in 1783. The AIAA History Committee and 3AF jointly organized the event....

On the occasion of the 70th anniversary of the Association Aeronautique et Astronautique de France, let us wish that cooperation will continue to flourish for many years to come.

NATERER APPOINTED AS NEW EDITOR-IN-CHIEF OF THE *JOURNAL OF THERMOPHYSICS AND HEAT TRANSFER*

On 30 September 2014, AIAA President Jim Albaugh formally appointed **Dr. Greg Naterer** as editor-in-chief of the *Journal of Thermophysics and Heat Transfer* (*JTHT*).

Currently Dr. Naterer is dean of the faculty of engineering and applied science and professor of mechanical engineering at Memorial University, St. John's, Newfoundland, Canada. He holds a B.Math. degree from the University of Waterloo in Applied Mathematics, and M.A.SC and Ph.D. degrees from the University of Waterloo in Mechanical Engineering. His research interests include heat transfer, convection, conduction, multiphase flows, hydrogen production, energy conversion, and microfluidics and nanotechnology for advanced energy systems.

Dr. Naterer fosters teaching and research excellence in a department that is experiencing tremendous growth. He has been lauded as a significant contributor to the development of Canada's next generation of engineers and a tremendous contributor to the content and quality of research in his field. Along with his teaching responsibilities, Naterer has served as principal investigator on numerous grants and contracts and is the author of several patents related to hydrogen production. Preceding his appointment at Memorial University in 2012, Naterer was on the faculty of engineering and applied science at the University of Ontario Institute of Technology.

An Associate Editor for *JTHT* since 2007, Naterer worked rigorously to ensure that accepted manuscripts met the highest standards of quality. He has a strong scholarly record in heat transfer, energy systems, and fluid mechanics, contributing to journals, conferences, and books. He is an AIAA Associate Fellow who has made significant contributions to the AIAA Thermophysics Committee for more than two decades, including serving as Chair from 2012 to 2014. He is a frequent thermophysics session chair at conferences, and he has served as conference and technical program chair for several of AIAA's forums.

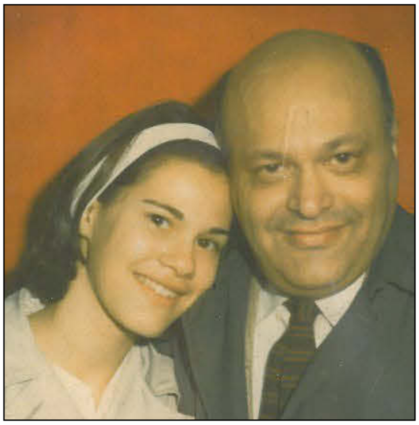
Dr. Naterer was selected from a competitive pool of applicants, and becomes only the second editor of *JTHT* and also the first editor-in-chief of one of AIAA's journals from outside the United States. The *Journal of Thermophysics and Heat Transfer* grew out of efforts by the Thermophysics TC to increase the number of thermophysics papers published in AIAA's journals. The journal was approved in 1986, and the first issue was published in January 1987; the founding editor, Prof. Al Crosbie, served as editor-in-chief continuously from 1987 to 2014. Since its inception, *JTHT* has been devoted to research that deals with the properties and mechanisms involved in thermal energy transfer and storage in gases, liquids, and solids.

During the editor search process, many enthusiastic recommenders noted Naterer's tireless support of AIAA over the years and his many technical accomplishments in the field. Looking toward the future, it is clear that Dr. Naterer's demonstrated commitment to the journal and to his profession will serve to enhance the quality, rigor, and reach of *JTHT*.

To submit articles to the *AIAA Bulletin*, contact your Section, Committee, Honors and Awards, Events, Precollege, or Student staff liaison. They will review and forward the information to the *AIAA Bulletin* Editor. See the AIAA Directory on page **B1** for contact information.

AIAA HEADQUARTERS WELCOMES INAUGURAL NORRIS SPACE VIEW INTERNS

Alexander "Al" Norris was an aerospace engineer whose 37-year career—like many AIAA members of his generation—spanned the ups and downs that came with the extraordinary evolution and growth of the aerospace industry in the 20th century. Born in 1914, Norris grew up in Brooklyn, New York. He attended New York University, graduating with a bachelor of science in mechanical engineering (1936) and master of science in engineering (1939). On the eve of World War II, Norris began working as an aircraft designer and stress engineer. His career took him from the propeller age to the jet age, and then into the space age. His resume included storied names like Republic Aircraft, Chase Aircraft, McDonnell Douglas, and Grumman Aircraft. He contributed to the U.S. Navy's development programs to design aircraft compatible with extreme polar environments. In Gibraltar and North Africa he helped reconstruct wreckage after aircraft disasters. His work with the Navy earned him the Meritorious Civilian Service Award for his expertise. His long career and numerous professional achievements were crowned with his work as a Senior Design Engineer on the design for the prototype of the hatch and contributing to the landing gear design of the Lunar Excursion Module.



Laurie and Alexander Norris

In August 2013, **Laurie Norris**, the daughter of the late Alexander R. Norris, contacted AIAA to propose a directed gift to the AIAA Foundation to fund two undergraduate internships over the next five years in memory of her father, ultimately establishing the Alexander R. Norris Space View Internships.

Laurie, along with her late husband Clarence Pearson, established a number of internships honoring her family and reflecting their passions and interests. She felt AIAA and the AIAA Foundation were a natural fit for internships to honor her father and his career in aerospace, and to help the generation of engineers learn about the aerospace industry first hand. "I selected AIAA to administer this internship in my father's name because of AIAA's mission and program fostering aerospace ingenuity and collaboration, which reflect my father's own professional career and commitment to aerospace," said Norris. "We are so appreciative of Laurie and Clarence's generosity," said Sandy Magnus, AIAA executive director and AIAA Foundation president. "Without their gift, this program would not be possible at this time. We look forward to the years ahead in fulfilling the goals of the internship and giving undergraduate students the opportunity to learn about all that the aerospace industry has to offer."

The interns will be working 7–10 hours a week from September to May at AIAA Headquarters in Reston, Virginia, limiting the program is limited to students from the accredited engineering programs in metropolitan Washington, DC. Recruitment began in early summer and the final evaluation and selection of candidates was completed in late September. The University of Maryland, College Park dominated the initial applicant pool, but AIAA did receive applicants from George Mason and Catholic universities as well. Next year, the goal is to have applicants from all seven eligible universities and colleges in the area.

The 2014–2015 Alexander R. Norris Space View Interns are **Samantha "Sam" Walters** and **Nathan Wasserman** from the University of Maryland, James A. Clark School of Engineering, Department of Aerospace Engineering. Both Sam and Nathan are seniors and come to AIAA with outstanding academic records, great community involvement, and early career accomplishments.

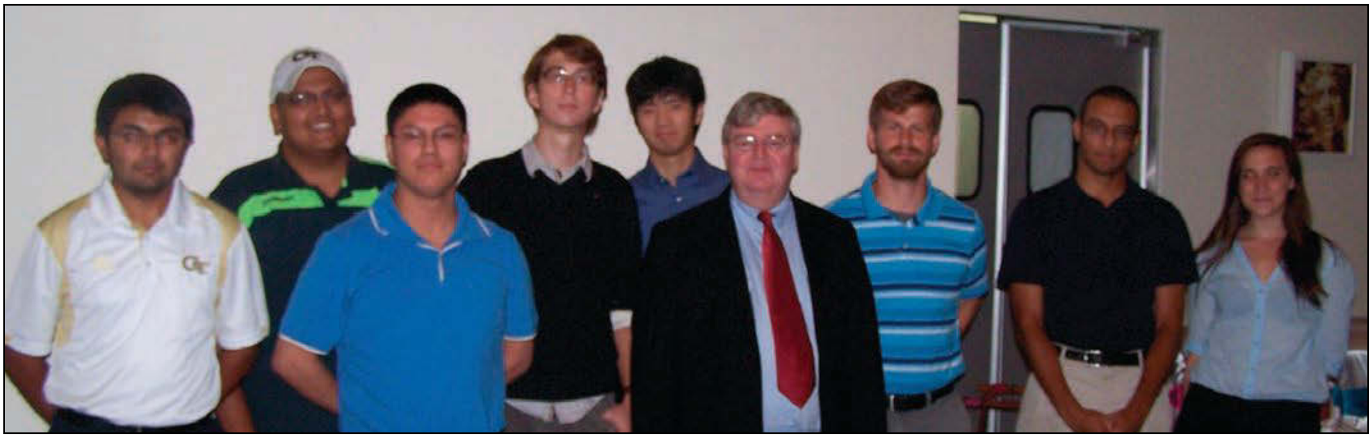
Sam led the University of Maryland AIAA Student Branch last year (2013–2014), something unusual for a junior. Her faculty advisor praised her ability to organize and reinvigorate the student branch and position it for continued growth and success. Sam has a passion for building a viable aerospace community and she looks forward to learning how AIAA operates at the professional level. She has completed two summer internships at the NASA Jet Propulsion Laboratory, first as the Mars Exploration Rover Engineering and Sequencing Support intern (2013) and as Mars Science Laboratory Operations intern (2014). She has also served as an undergraduate research assistant since 2012. In addition to pursuing her bachelors of science in aerospace engineering (BSAE), she is minoring in creative writing. When asked about her expectations from this experience, Sam said, "I hope to learn more about what it really means to be a professional aerospace engineer. In school, I learn the equations and theory behind the work that I will be doing once I graduate, but I know very little about the profession itself. I hope to take the networking skills, knowledge of policy, and any other real-world experiences that I gain from this internship, and use them in my future career, as I transition from a student to a young professional in the aerospace engineering community."

Nathan is equally active academically and in the community and is pursuing his BSAE and taking courses in engineering leadership. Nathan held summer internships with Jacobs Engineering as a data collector (2011), a year-long internship with FlexEl LLC (a privately funded spin-out company from the University of Maryland) where he was a senior engineering intern (2012–2013), and with Sikorsky Aircraft. Following his summer internship as ground test co-op engineer (2013) with Sikorsky, Nathan made the difficult decision to delay his senior year and continue in a full-time position as a risk manager (2013–2014) with Sikorsky. In addition, Nathan is a teaching assistant with UMD's Women in Engineering Flexus Program (2014), an official with UMD Campus Recreation and Sports (2011–2014), and a teaching assistant for the Johns Hopkins Center for Talented Youth (2014). He is also a leader in the UMD Hillel center helping to organize the Repair the World Alternative Break program, which helps students explore and combat emerging achievement and education gaps in America. Nathan is looking forward to connecting with "current students and young professionals to AIAA in ways never done before. I am looking forward to playing a role in integrating the new generation of aerospace professionals with AIAA and all it has to offer."

Sam and Nathan will work on a variety projects throughout the year with the goal of interacting with each of AIAA's major HQ divisions. They will support and attend AIAA SciTech 2015, and will report on their experience at various times through the *AIAA Bulletin*, *AIAA Momentum*, and AIAA's social media platforms.

AIAA ATLANTA SECTION HOSTS TALK

On 23 September, the AIAA Atlanta Section hosted Simon Pickup, Strategic Marketing Director, Airbus Americas Sales, Inc. Mr. Pickup discussed recent restructuring of EADS into the Airbus Group, comprised of three divisions, Airbus, Airbus Defense & Space, and Airbus Helicopters. Mr. Pickup elaborated on the Airbus Division's development of A320neo and A350 models to compete with recent Boeing offerings. He presented the impressive number of over 14,000 Airbus orders since the delivery of the first A300 in 1974. The student members attending from Georgia Tech and Southern Polytechnic State University received scale models of the A350.



Simon Pickup With AIAA Student Branch Leaders (from left to right): Rohan Deshmukh (Georgia Tech Secretary), Hasan Tawab (Georgia Tech Vice-Chair), Josue Cristancho (Founding Chair, Southern Polytechnic State University (SPSU) Student Branch), Jefferey Illg (SPSU Chair), Ken Khamphoumy (SPSU Vice-Chair), Simon Pickup, Aaron Johnson (SPSU), Divanny Pena (SPSU), Elizabeth Balga (Georgia Tech Chair).

The 2014 Reuben H. Fleet Scholarship recipients (left to right): Jennifer Rhymer (AIAA San Diego Section Chair), Deepak Atyam (UCSD), Jin Oh (UCSD), Alex Fleet (grandson of Reuben H. Fleet), Robert Bertino (UCSD), Juan Avila (SDSU), Robin Felver (UCSD), Greg Marien (Scholarship Coordinator), Jennifer Wood (not pictured).

REUBEN H. FLEET SCHOLARSHIPS AWARDED BY THE SAN DIEGO SECTION IN MAY

At the AIAA San Diego Section Honors and Awards Banquet on 15 May, the AIAA San Diego Section Reuben H. Fleet Scholarships were awarded. Since 1983, 165 students have received the scholarship, which is made possible by the Reuben H. Fleet Foundation at The San Diego Foundation.

OBITUARIES

AIAA Fellow Marble Died in August

Frank E. Marble died on 11 August. He was 96.

Dr. Marble helped develop innovations that made rockets more efficient and dampened the noise generated by the turbines in jet engines. He also trained generations of scientists at JPL and Caltech, where he continued working well after his 1989 retirement as a professor of mechanical engineering and jet propulsion.

Marble received his bachelor's and master's degrees from the Case Institute of Technology. During World War II, he worked in a government lab, and in 1948, he received his doctorate in aeronautics and mathematics from Caltech.

Dr. Marble served on committees advising NATO, NASA, and the U.S. Air Force, and he was a visiting professor at Cornell, MIT, among others. Marble's contributions were recognized with the Daniel Guggenheim Medal, the AIAA Wright Brothers Lectureship in Aeronautics, and the AIAA Plasmadynamics and Lasers Award.

AIAA Senior Member Hinners Died in September

Noel Hinners died on 5 September. He was 78 years old.

Hinners studied geology at Rutgers University. He pursued geochemistry as a master's student at Caltech, before attending Princeton for a Ph.D. in geophysics and geochemistry.

In 1963 Dr. Hinners accepted a job at Bellcomm in Washington, DC, a major contractor for the Apollo program. He led the effort to select Apollo lunar landing sites and helped develop lunar field geology for Apollo and train astronauts for it.

Dr. Hinners joined NASA in 1972 as director of lunar programs. Promoted to associate administrator for space science, he championed planetary research. He left NASA in 1979 to become the first scientist to run the new National Air and Space Museum, focusing on the intellectual scope of the curatorial departments and greater attention to the space sciences.

He returned to NASA in 1982 as director of Goddard Space Flight Center and later became the agency's first associate deputy administrator and chief scientist. After leaving NASA in 1989, he joined Martin Marietta, where he took part in a wide range of planetary mission activities until his retirement in 2002.

AIAA Fellow Tiffany Died in October

Charles (Chuck) F. Tiffany, 84, died on 12 October.

He attended Macalester College and the University of Minnesota, and received degrees in civil engineering and mathematics. Shortly after, he joined the Boeing Aircraft Company in Seattle as a stress analyst.

Though Mr. Tiffany's career with Boeing (28 years) and the U.S. Air Force (eight years), he progressed to executive vice-president of the Boeing Military Airplane Company. After retiring from Boeing in 1988, he was a private consultant on aircraft and aerospace vehicle structures for the Air Force, the Department of Defense, NASA, FAA, National Academy of Engineering (NAE), National Research Council, among others.

Tiffany's area of expertise was airframe and propulsion structural design and damage tolerance. He led the development of new structural standards and specifications for improving aircraft safety and durability. He received numerous awards and honors, including the Von Karman Memorial Award, ASME's "The Spirit of St. Louis Medal," the John W. Lincoln Award, the FAA Gold Medal, and the AIAA Structures, Material and Dynamics Award.

Mr. Tiffany's work was captured in numerous technical papers and reports, including most recently, "Aging of U.S. Air Force Aircraft" and "Threats to Aircraft Structural Safety, Including a Compendium of Selected Structural Accidents/Incidents."

AIAA Associate Fellow Knemeyer Died in October

Franklin H. Knemeyer, a pioneer in naval aviation science, died on 15 October. He was 92 years old.

Mr. Knemeyer studied aeronautics at the California Institute of Technology. He graduated in 1944 and continued at Cal Tech for his master's degree (1948). He also served as a naval aviation ordnance officer during World War II.

Mr. Knemeyer began working for NASA Jet Propulsion Laboratory, which in turn led to a 34-year career at the Naval Ordinance Test Station (Naval Weapons Center), China Lake, CA. Under his leadership were many accomplishments in science and engineering related to weapons development. Among his awards were the Navy Distinguished Civilian Service Award, the Navy's highest award to a civilian, the Navy's Meritorious Civilian Service Award, and the L.T.E. Thompson Award.

CALL FOR PAPERS FOR *JOURNAL OF AEROSPACE INFORMATION SYSTEMS*

Special Issue on Optimal Decision Making in Aerospace Systems

The *Journal of Aerospace Information Systems* is devoted to the applied science and engineering of aerospace computing, information, and communication. Original archival research papers are sought that include significant scientific and technical knowledge and concepts. The *Journal* publishes qualified papers in areas such as aerospace systems and software engineering; verification and validation of embedded systems; the field known as "big data," data analytics, machine learning, and knowledge management for aerospace systems; human-automation interaction; and systems health management for aerospace systems. Applications of autonomous systems, systems engineering principles, and safety and mission assurance are of particular interest. Articles are sought that demonstrate the application of recent research in computing, information, and communications technology to a wide range of practical aerospace problems in the analysis and design of vehicles, onboard avionics, ground-based processing and control systems, flight simulation, and air transportation systems.

Information about the organizers of this special issue as well as guidelines for preparing your manuscript can be found in the full Call for Papers in Aerospace Research Central (ARC); arc.aiaa.org. The journal website is **http://arc.aiaa.org/loi/jais**.

This special issue will focus on algorithms for optimal decision making in aerospace systems. In many complex aerospace applications, systems must interact with dynamic environments, be robust to uncertainty in sensor information, and reliably balancing safety and efficiency. Recent advances in decision theoretic optimization have shown tremendous promise in addressing the challenges of engineering such systems.

Key research areas in the special issue include:

- Decision theoretic models: MDPs, POMDPs
- Multi-agent systems: MMDPs, Dec-POMDPs, POSGs, i-POMDPs
- Solution methods: dynamic programming, online planning, robust optimization
- Approximation techniques: structured approaches, Monte Carlo methods, dimensionality reduction, linearization
- Learning algorithms and adaptive methods
- Application domains: decision support for air traffic control, mission planning, unmanned aircraft, autonomous spacecraft, etc.
- Verification and validation methods for decision-making systems

Deadline: Submissions are due by **15 December 2014**.
Anticipated Publication Date: **May 2015**.
Contact Email: Mykel Kochenderfer, mykel@stanford.edu

CALL FOR NOMINATIONS

Nominations are being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 February**. Any AIAA member in good standing may serve as a nominator and are urged to carefully read award guidelines to view nominee eligibility, page limits, letters of endorsement, etc.

AIAA members may submit nominations online after logging into **www.aiaa.org** with their user name and password. You will be guided step-by-step through the nomination entry. If preferred, a nominator may submit a nomination by completing the AIAA nomination form, which can be downloaded from www.aiaa.org.

Aerospace Power Systems Award
This award is presented for a significant contribution in the broad field of aerospace power systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and processing of aerospace power.

Air Breathing Propulsion Award
This award is presented for meritorious accomplishment in the science of air breathing propulsion, including turbomachinery or any other technical approach dependent on atmospheric air to develop thrust, or other aerodynamic forces for propulsion, or other purposes for aircraft or other vehicles in the atmosphere or on land or sea.

Daniel Guggenheim Medal
The industry-renowned Daniel Guggenheim Medal honors those who make notable achievements in the advancement of aeronautics. AIAA, ASME, SAE, and AHS sponsor the award.

Energy Systems Award
This award is presented for a significant contribution in the broad field of energy systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and conservation of energy.

George M. Low Space Transportation Award
This award is presented for a timely outstanding contribution to the field of space transportation. (Presented even years)

Haley Space Flight Award
This award recognizes outstanding contributions by an astronaut or flight test personnel to the advancement of the art, science, or technology of astronautics. (Presented even years)

J. Leland Atwood Award
This award is given to an aerospace engineering educator to recognize outstanding contributions to the profession. AIAA and ASEE sponsor the award. Note: Nominations should be submitted to ASEE (**www.asee.org**) no later than **15 January**.

Missile Systems Award—Technical Award
This award is given for a significant accomplishment in developing or using technology that is required for missile systems.

Missile Systems Award—Management Award
This award is presented for a significant accomplishment in the management of missile systems programs.

Propellants and Combustion Award
This award is presented for outstanding technical contributions to aeronautical or astronautical combustion engineering.

Space Automation and Robotics Award
This award recognizes leadership and technical contributions by individuals and teams in the field of space automation and robotics. (Presented odd years)

Space Science Award
This award is given to an individual for demonstrated leadership of innovative scientific investigations associated with space science missions. (Presented even years)

Space Operations and Support Award
This award is presented for outstanding efforts in overcoming space operations problems and assuring success, and recognizes those teams or individuals whose exceptional contributions were critical to an anomaly recovery, crew rescue, or space failure. (Presented odd years)

Space Processing Award
This award is presented for significant contributions in space processing or in furthering the use of microgravity for space processing. (Presented odd years)

Space Systems Award
This award recognizes outstanding achievements in the architecture, analysis, design, and implementation of space systems.

von Braun Award for Excellence in Space Program Management
This award gives recognition to an individual(s) for outstanding contributions in the management of a significant space or space-related program or project.

William Littlewood Memorial Lecture
The lecture, sponsored by AIAA and SAE, focuses on a broad phase of civil air transportation considered of current interest and major importance. Nominations should be submitted by **1 February** to SAE at **www.sae.org/news/awards/list/littlewood**.

Wright Brothers Lectureship in Aeronautics
The Wright Brothers Lectureship in Aeronautics emphasizes significant advances in aeronautics by recognizing major leaders and contributors. (Presented odd years)

Wyld Propulsion Award
This award is presented for outstanding achievement in the development or application of rocket propulsion systems.

For more information, contact Carol Stewart, Manager, AIAA Honors and Awards, carols@aiaa.org or 703.264.7623.

Seeking New Members

The **Aircraft Operations Technical Committee** is being reinvented and is actively seeking new members. If you would like to contribute to air transportation operations in the United States and beyond, please contact the committee chair, Karen Marais, at kmarais@purdue.edu.

This year marked the first full year that the new **Spacecraft Structures Technical Committee** has operated in place of the former Gossamer Spacecraft Program Committee. This new technical committee is focused on the unique challenges associated with structural systems that operate in space-based environments. This committee is seeking candidates from academic, industry, and government organizations who are actively involved in the development, application, and/or promotion of spacecraft structural systems that operate in space-based environments. This committee is particularly interested in the challenges of design, analysis, fabrication, and testing of those lightweight structural systems that can be ground tested only in a simulated zero gravity condition, and are subjected to launch loads, deployment loads, and the space environment. For more information, see **https://info.aiaa.org/tac/adsg/SCSTC/default.aspx**.

Upcoming AIAA Continuing Education Courses

Workshop and Courses at AIAA Science and Technology Forum and Exposition 2015 (AIAA SciTech 2015)
www.aiaa-scitech.org/ContinuingEd

3–4 January 2015

Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-On Training Using CIFER®

Instructor: Dr. Mark B. Tischler

The objectives of this two-day short course is to 1) review the fundamental methods of aircraft and rotorcraft system identification and illustrate the benefits of their broad application throughout the flight vehicle development process; and 2) provide the attendees with an intensive hands-on training of the CIFER® system identification, using flight test data and 10 extensive lab exercises. Students work on comprehensive laboratory assignments using student version of software provided to course participants (requires student to bring NT laptop). The many examples from recent aircraft programs illustrate the effectiveness of this technology for rapidly solving difficult integration problems. The course will review key methods and computational tools, but will not be overly mathematical in content. The course is highly recommended for graduate students, practicing engineers, and managers.

Key Topics

- Overview of system identification methods and applications
- Flight testing and instrumentation for handling-qualities and manned/unmanned control system development
- Simulation model fidelity analysis and design model extraction from prototype flight testing
- Flight test validation and optimization of aircraft dynamics and control
- Hands-on training in system identification training using CIFER®
- Students work on 10 comprehensive labs on model identification and verification using flight test data

Who Should Attend

The course is intended for practicing engineers and graduate students interested in learning the principles and applications of system identification for aircraft and rotorcraft. The course assumes some basic knowledge of the concepts of: dynamics, frequency-responses, transfer functions, and state-space representations. The course is not highly mathematical and no experience with other tools is a prerequisite.

3–4 January 2015

Best Practices in Wind Tunnel Testing

Instructors: David Cahill, Mark Melanson, and Allen Arrington

This course provides an overview of important concepts that are used in many wind tunnel test projects. The course is based largely on AIAA standards documents that focus on ground testing concepts. In particular, the course will address project management aspects of executing a testing project, the use and calibration of strain gage balances, the use of measurement uncertainty in ground testing, and the calibration of wind tunnels.

Key Topics

- Wind tunnel test processes
- Measurement uncertainty analysis for wind tunnel testing
- Internal strain gage balances for wind tunnel testing
- Aero-thermal calibration of wind tunnels

Who Should Attend

The course is designed for engineers who are involved with ground testing, particularly wind tunnel testing. The course will be beneficial to all levels of ground test engineers; it could be a primer for engineers new to testing but also will be of value to senior engineers as it will include lessons learned that can be directly applied by test project leaders.

3–4 January 2015

Third International Workshop on High-Order CFD Methods

Workshop Co-Chairs: H. T. Huynh and Norbert Kroll

High-order numerical methods for unstructured meshes offer a promising route to solving complex industrial fluid flow problems by combining superior accuracy with geometric flexibility. The 3rd International Workshop on High-Order CFD Methods is being organized by a committee of 21 international members co-chaired by H. T. Huynh of NASA Glenn Research Center and Norbert Kroll of DLR.

Workshop Objectives

- To provide an open and impartial forum for evaluating the status of high-order methods (order of accuracy > 2) in solving a wide range of flow problems
- To assess the performance of high-order methods through comparison to production 2nd order CFD codes widely used in the aerospace industry with well-defined metrics
- To identify pacing items in high-order methods needing additional research and development in order to proliferate in the CFD community

The workshop is open to participants all over the world. To be considered as speakers, participants need to complete at least one sub-case.

A number of fellowships will be provided by Army Research Office (ARO) and NASA to pay registration fees for undergraduate and graduate students to attend the workshop and present their work. If you are interested in applying for this registration waiver, please contact H. T. Huynh at huynh@grc.nasa.gov. For more information, please visit the https://www.grc.nasa.gov/hiocfd/.

4 January 2015

Introduction to Integrated Computational Materials Engineering (ICME)

Instructor: Dr. Vasisht Venkatesh

Designed to provide an overview of integrated computational materials engineering (ICME), this course offers a primer on the various types of models and simulation methods involved in ICME. It is aimed at providing a general understanding of the critical issues relative to ICME, with the goal of increasing participants' knowledge of materials and process modeling capabilities and limitations. The important aspects of linking materials models with process models and subsequently to component design and behavior analysis models will be reviewed.

Key Topics

- Obtain awareness of ICME as an emerging technology area
- Understand general models and simulation methods involved in ICME
- Articulate critical issues/challenges with ICME
- Build awareness of materials and process modeling capabilities and limitations
- Understand important aspects of linking material models with process models and their integration into component design and behavior analysis.

Who Should Attend

This course is aimed at materials, mechanical design, and manufacturing engineers; program managers; and engineering management looking to introduce or apply ICME methods in the future. This course will not provide hands-on training, but rather will provide an appreciation for the types of models available, their benefits, and how various model outputs should be interpreted.

8–9 January 2015

Fundamentals and Applications of Modern Flow Control

Instructors: Daniel Miller, Louis N. Cattafesta III, and Tony Washburn

Modern passive and active flowfield control is a rapidly emerging field of significant technological importance to the design and capability of a new generation of forthcoming air-vehicle systems, spawning major research initiatives in government, industry, and academic sectors of aeronautics. This completely revised two-day short course will address introductory fundamentals as well as several emerging air-vehicle applications of modern aerodynamic flowfield control techniques. The first day will cover a brief overview of the fundamentals of flow control, including basic concepts, terminology, history, strategies/techniques, actuators, sensors, modeling/simulation, and closed-loop control. The second day will cover applications of flow control to current and next-generation air vehicle systems, including vehicle propulsion integration, airfoil control, noise suppression, wake control, and some forthcoming non-aeronautical applications. A multi-institutional team of eight researchers from government, industry, and academia will cooperatively teach this course.

Key Topics

- Concepts, terminology, and history of flow control
- Flow control strategies
- Actuators and sensors
- Modeling and simulation techniques
- Closed-loop flow control
- Air vehicle applications: propulsion, airfoil, dynamic flowfield, non-aero apps

Course at AIAA Defense and Security Forum 2015 (AIAA DEFENSE 2015)
www.aiaa-defense.org/ContinuingEd

8–9 March 2015

Overview of Missile Design and System Engineering

This course provides an overview of missile design and system engineering. A system-level, integrated method is provided for missile design, technologies, development, analysis, and system engineering activities in addressing requirements such as cost, performance, risk, and launch platform integration. The methods presented are generally simple closed-form analytical expressions that are physics-based, to provide insight into the primary driving parameters. Sizing examples are presented for rocket-powered, ramjet-powered, and turbo-jet powered baseline missiles as well as guided bombs. Typical values of missile parameters and the characteristics of current operational missiles are discussed as well as the enabling subsystems and technologies for missiles and the current/projected state of the art. Videos illustrate missile development activities and performance. Attendees will receive a copy of the course notes.

Key Topics

- Key drivers in the missile propulsion design and system engineering process
- Critical tradeoffs, methods, and technologies in propulsion system sizing to meet flight performance and other requirements
- Launch platform-missile integration
- Sizing examples for missile propulsion
- Missile propulsion system and technology development process


WHEN THIS IS YOUR BACKYARD, YOU CAN'T HELP BUT EXPLORE.
When you've been in space long enough, you start to feel at home. We've been pushing the limits of what's possible out here since the dawn of the space age. For over 60 years, we at Northrop Grumman have been igniting the flame for space exploration—inspiring generations to stop and look up. From building the lunar module that led to one small step for man, to realizing the global dream that is the James Webb Space Telescope, the Great Pyramid of our generation. We've been here all along, and we aren't going anywhere but up.
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